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Comparison of Tools to Quantify Wildfire Smoke Influenced Ozone Concentrations

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Outline

Goal: *Identify/quantify smoke-influenced ozone concentrations*

- Why is this important?
- Common statistical tools
  - Generalized additive model (GAM)
  - Matching days analysis
- Comparison of tools
  - Case study: 2020 wildfire season in Clark County, Nevada

Exceptional Events

- Enhanced ozone concentrations caused by **exceptional events (EE)** may be omitted from a region's **design value.**
- The design value determines a region's air quality status.
  Design Value > NAAQS puts a region in "non-attainment."
- Each day that exceeds the 0.070 ppm ozone standard has the potential to put a region out of attainment.

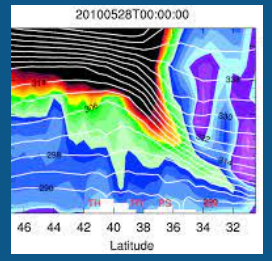
Exceptional Events

Wildfires

Prescribed fires

High wind dust events

Stratospheric ozone intrusions



Seismic activities

Volcanic activities

Exceptional Events (cont'd)

- A region must provide evidence that the high-ozone event was exceptional in the form of an **Exceptional Event Demonstration.**
- Wildfire EE guidance lists three tiers of evidence that may be included in an EE demonstration based on the circumstances of the event.
- Tier 3 EE guidance recommends two analytical tools that may provide evidence that an external source (e.g., wildfire smoke) enhanced a region's ozone concentration:
  1. Statistical Regression Modeling (GAM)
  2. Matching Day Analysis (MDA)

GAM

- Widely used and accepted in the scientific community (extensive literature documenting use)
- Requires statistical expertise/technical skill

- **Estimate the influence of an external source of ozone** on local concentrations
- Compare **"expected" ozone concentrations based on meteorological conditions** to actual ozone concentrations

MDA

- Little documentation of use/validation in the scientific community
- Requires basic statistical knowledge

GAM

- Identify **predictor variables** for daily ozone
  - A predictor variable provides information to estimate the response variable
  - Mainly comprised of meteorological parameters
  - Can incorporate other measured gas-phase species
- Model MDA8 ozone (response variable) from addition of smooth functions of **predictor variables** for daily ozone

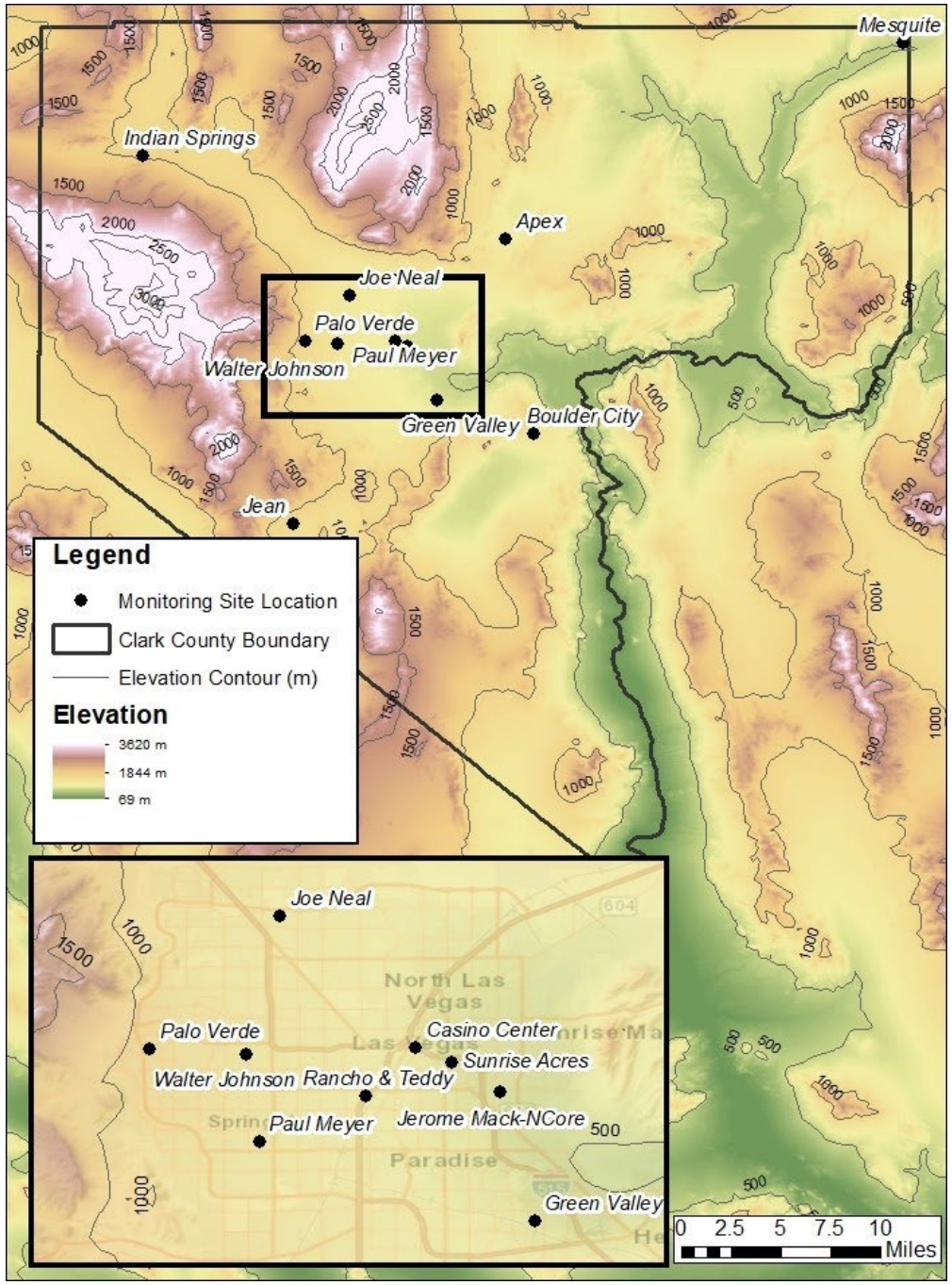
$$g(\mathrm{E}(Y)) = \beta_0 + f_1(x_1) + f_2(x_2) + \cdots + f_m(x_m).$$

- Examine **residual values** to identify/quantify influence of exceptional source on MDA8 ozone
  - *Residual = Actual MDA8 ozone – Modeled MDA8 ozone*
  - **A high, positive residual provides evidence for an external source of ozone**
- EPA documentation establishes a threshold for residual analysis in EE demonstrations

MDA

- Compare MDA8 ozone on a date with suspected wildfire influence to MDA8 ozone on meteorologically similar days (matching days). Evidence of an exceptional source of ozone exists if MDA8 ozone is significantly higher than on matching days.
- Matching days may be identified by comparing local and synoptic scale meteorological conditions:
  - Local: site-specific measurements of temperature, wind, moisture, irradiance, etc., at the surface and aloft.
  - Synoptic:
    - Regional meteorological patterns (high- and low-pressure systems).
    - Regional correlation in temperature, wind, and moisture at the surface and aloft.
    - Air transport patterns (HYSPLIT back-trajectories).

Case Study:
Comparison of GAM and MDA in Clark County, NV (2020)



Goal

- Evaluate the ability of each tool to correctly identify an external source of ozone on days with enhanced ozone concentrations.
- Compare the magnitude of external ozone estimated by each tool.

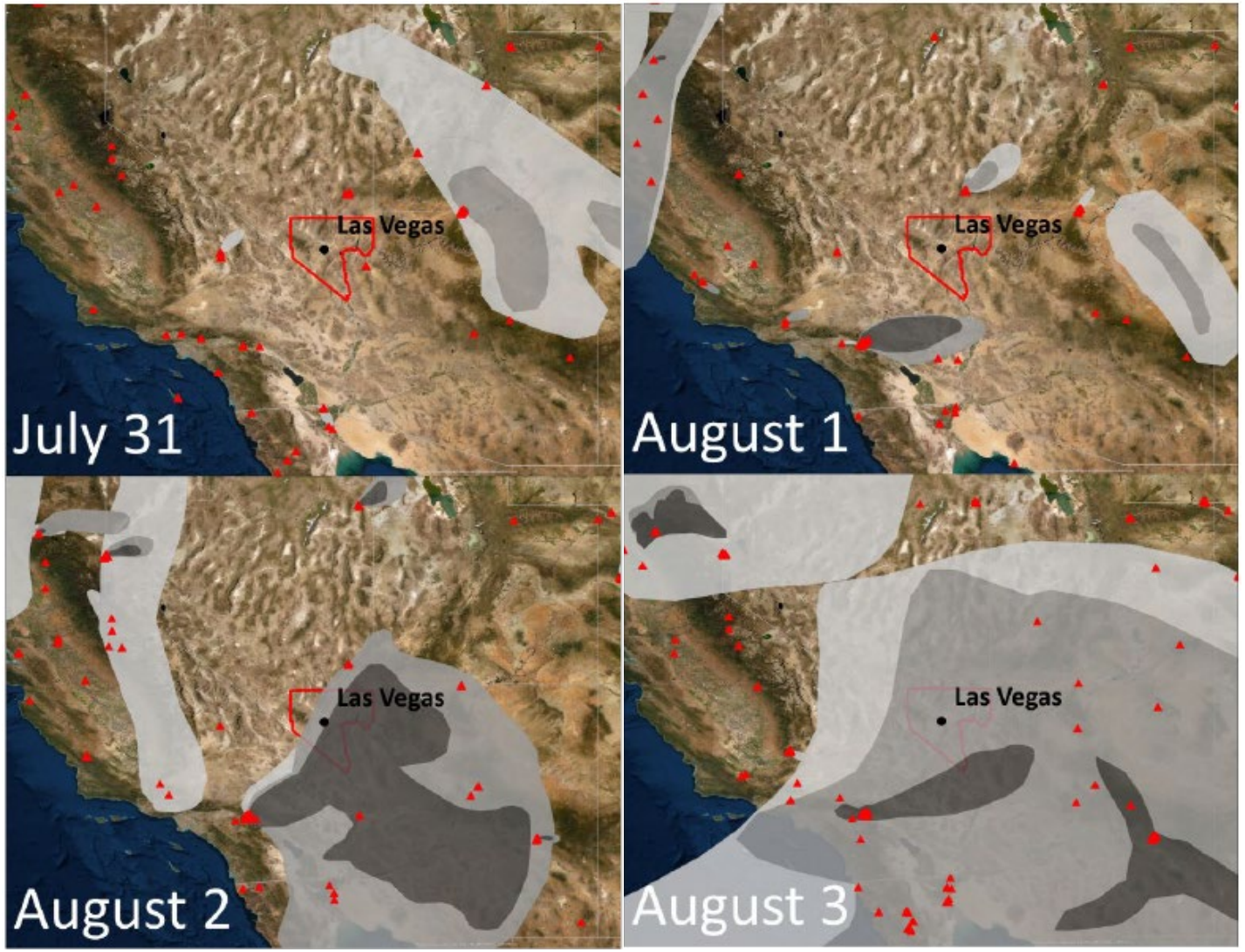
Photo Credit: https://abcnews.go.com/US/smoke-fires-west-affecting-air-quality-cities-1000/story?id=79361284

Methodology

- An “event set” of smoke-influenced days were identified from the 2020 wildfire season in Clark County, NV.
  - High MDA8 ozone
  - Evidence of wildfire-smoke influence
- A “non-event set” of dates without smoke influence was identified:
  - High MDA8 ozone (>65 ppb)
  - No evidence of smoke influence (per HMS smoke and 24-hr HYSPLIT back-trajectory)
  - Selected from ozone-season dates (April 1 to September 30) from 2014-2020 in Clark County, NV

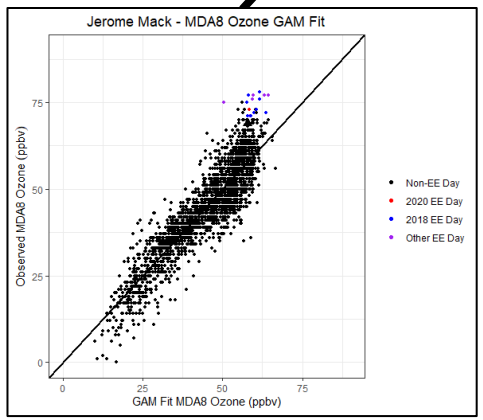
Example Event Set Date: August 3, 2020

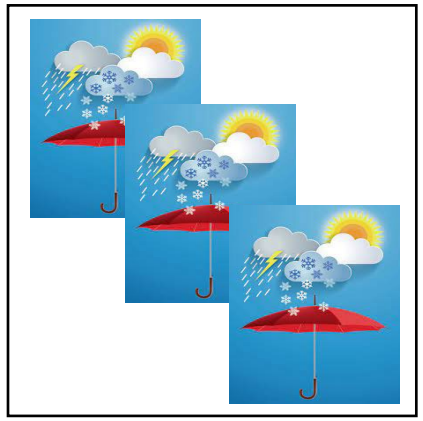
AQS Site	MDA8 Ozone (ppb)
Boulder City	72
Green Valley	72
Indian Springs	71
Jean	73
Joe Neal	81
Paul Meyer	78
Walter Johnson	82



Methodology (cont'd)

- Create GAMs for each site across available data and obtain residual values for the event set and the non-event set.
- Perform MDA for both event and non-event set dates.
- Calculate the residual per date as the difference between the observed ozone and the average MDA8 ozone across matching days.





GAM Specifications

- One model created per each AQS monitoring site
- All ozone-season dates (April 1 to September 30) from 2014-2020
- Data sourced from AQS, National Centers for Environmental Protection (NCEP), HYSPLIT, and upper-air soundings (University of Wyoming)
- Achieved R^2 values range from 0.55 to 0.65

Parameter	Data Source
Day of Year	--
Previous Day MDA8 Ozone	Monitor Data
Avg. Daily Temperature	Monitor Data/NCEP
Maximum Daily Temperature	Monitor Data/NCEP
Temperature Range	Monitor Data/NCEP
Avg. Daily pressure	Monitor Data/NCEP
Avg. Daily Wind Speed	Monitor Data/NCEP
Avg. Daily Wind Direction	Monitor Data/NCEP
18 UTC HYSPLIT Distance	HYSPLIT
22 UTC HYSPLIT Distance	HYSPLIT
CAPE	Upper-air Soundings
LCL Pressure	Upper-air Soundings
Mixing Layer Potential Temperature	Upper-air Soundings
Mixed Layer Mixing Ratio	Upper-air Soundings
500-1000 hPa Thickness	Upper-air Soundings
12 UTC 1km Avg. Relative Humidity	Upper-air Soundings

MDA Specifications

- One analysis per event and non-event set date.
- Set of possible matching days includes all ozone-season dates (April 1 to September 30) from 2014-2020. Verified EE dates are excluded.
- Data sourced from AQS, NCEP, HYSPLIT, and upper-air soundings (University of Wyoming).

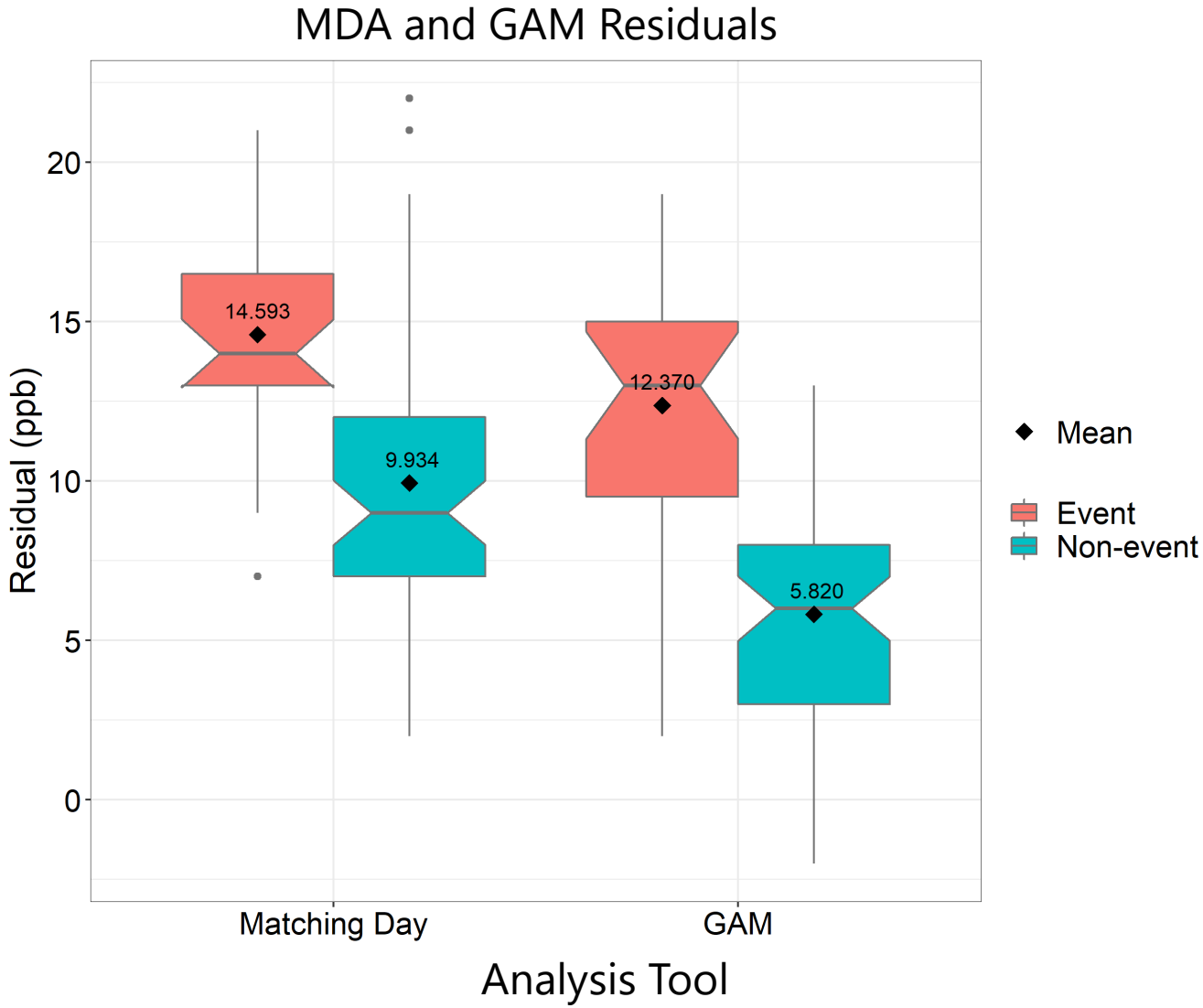
Additional parameters that could enhance the MDA analysis:

- Ambient NO_x concentrations
- Day of week effects
- Previous day ozone concentration
- Wind speeds at time of peak ozone formation

Parameter	Data Source
18 UTC HYSPLIT Trajectory	HYSPLIT
22 UTC HYSPLIT Trajectory	HYSPLIT
Maximum daily temperature	Monitor Data/NCEP
Average daily temperature	Monitor Data/NCEP
Resultant daily wind direction	Monitor Data/NCEP
Resultant daily wind speed	Monitor Data/NCEP
Average daily wind speed	Monitor Data/NCEP
Average daily relative humidity (RH)	Monitor Data/NCEP
Precipitation	Monitor Data/NCEP
Total daily global horizontal irradiance (GHI)	UNLV Measurement and Instrumentation Data Center (MIDC)
4:00 p.m. LST mixing layer mixing ratio	Upper air sounding
4:00 p.m. LST lifted condensation level (LCL)	Upper air sounding
4:00 p.m. LST convective available potential energy (CAPE)	Upper air sounding
4:00 p.m. LST 1,000 to 500-mb thickness	Upper air sounding
Daily surface meteorological map	NCEP
Daily 500-mb meteorological map	NCEP

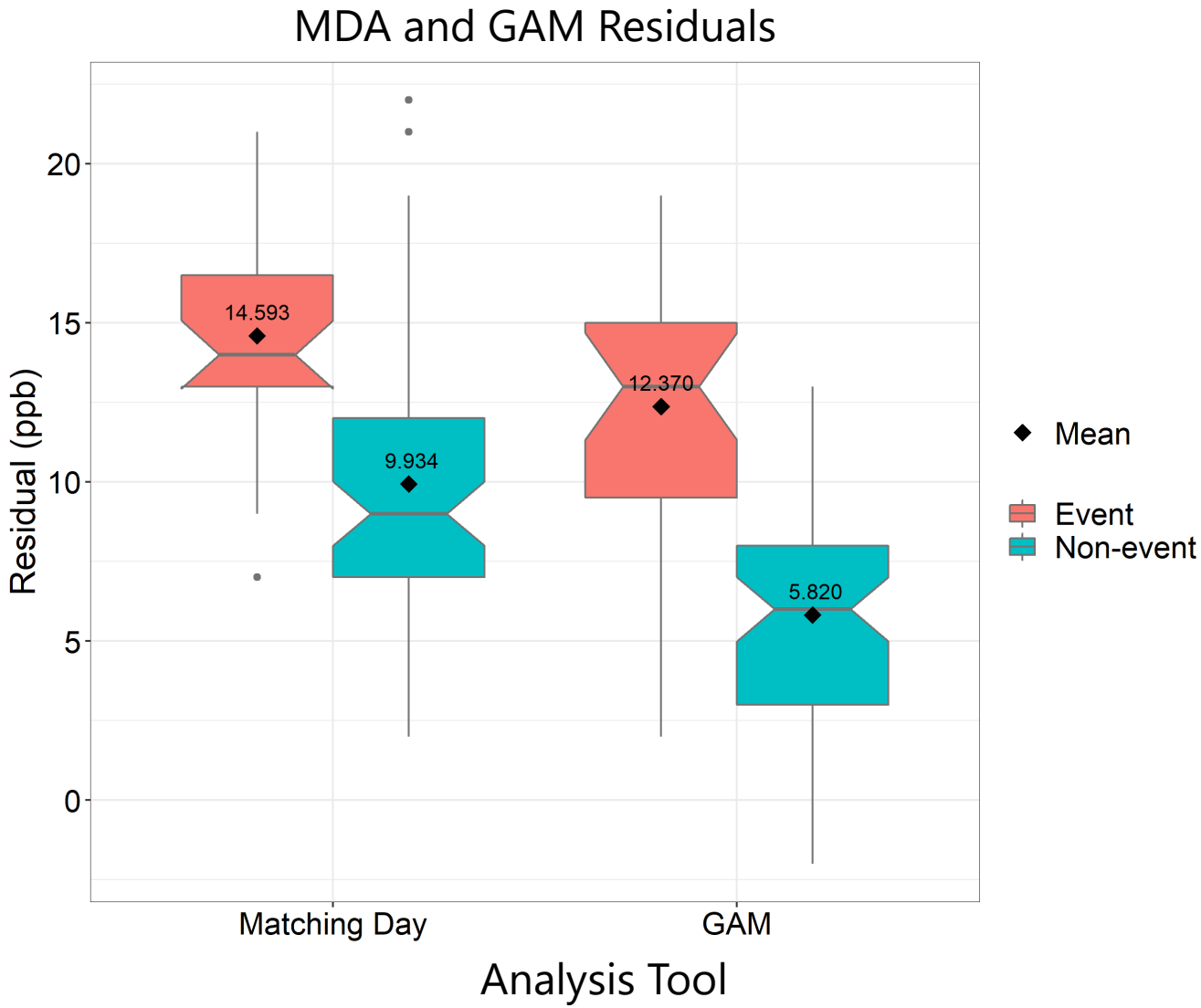
Results: Event vs. Non-Event Residuals

- Both GAM and MDA show **significantly higher residuals for the event set** (p-value < 0.05).
- GAM shows a larger difference (6.5 ppb) than MDA (4.4 ppb). This could indicate that a GAM is better able to distinguish an exceptional source.



Results: GAM vs. MDA Residual Magnitudes

- Both GAM and MDA show **positive residuals for the non-event set.** Both analyses underpredict ozone on high ozone days (**non-event bias**).
- MDA residuals are higher per category than GAM residuals. MDA estimates a larger external influence on MDA8 ozone than GAM.



Conclusions

- Both GAM and MDA are effective tools to identify an exceptional source of ozone.
- **High-ozone, non-event bias** should be evaluated for either tool prior to making definitive conclusions.
- MDA may be a more viable option when rigorous statistical analyses are not required.

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Questions?

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