Atmospheric and
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Verisk

Evaluating the Ability of Statistical and Photochemical Models to Capture the Impacts of Biomass Burning Smoke on Urban Air Quality in Texas

AQRP Project 22-003

Presented to:
University of Texas-Austin and
Texas Commission on Environmental Quality

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Three Chemical Stages of Smoke Ozone (O_3) Formation

Verisk

Near-Source Chemistry (0-6 hr)

Rapid O_3 formation
Depletion of initial NO_x and HRVOCs

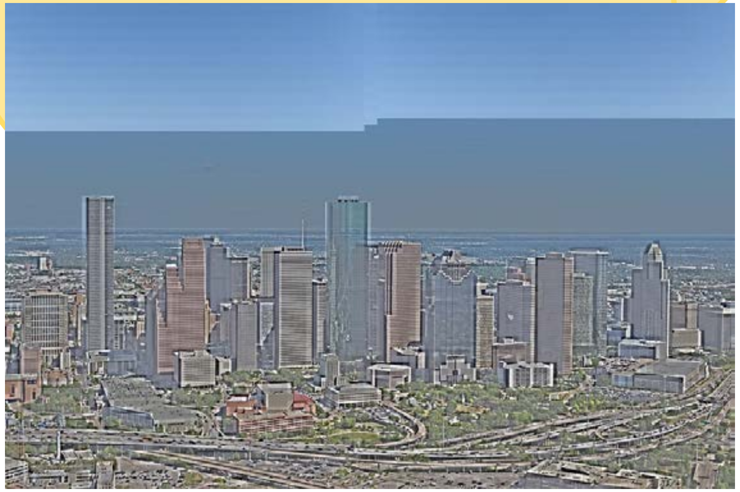
Long-range Transport (6-48 hr)

Net O_3 formation settles to ~ 0.2 dO_3/dCO

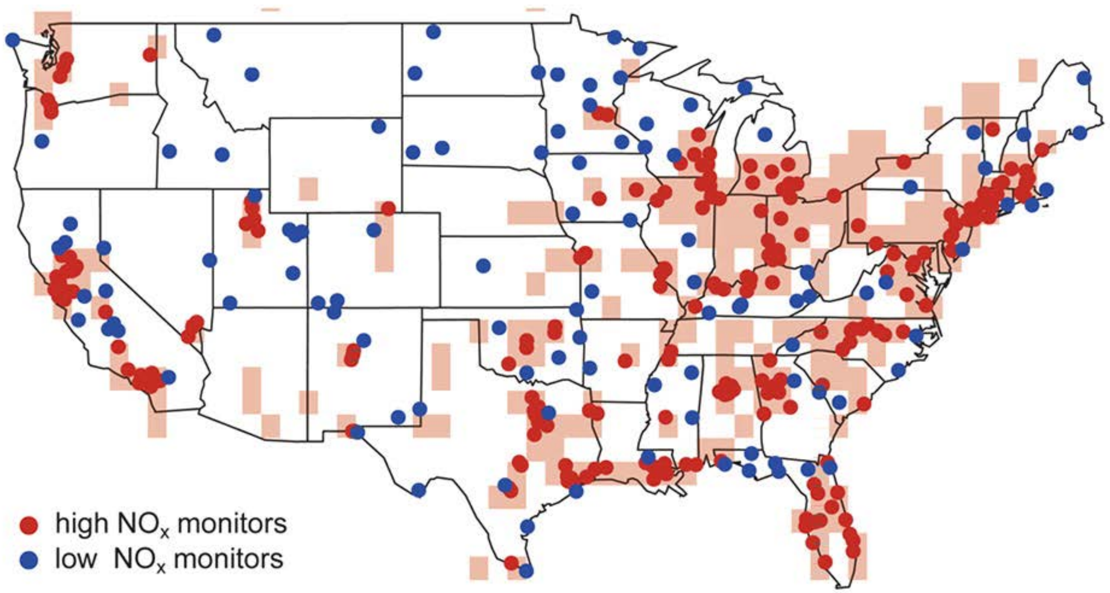
Mixing with Urban Air

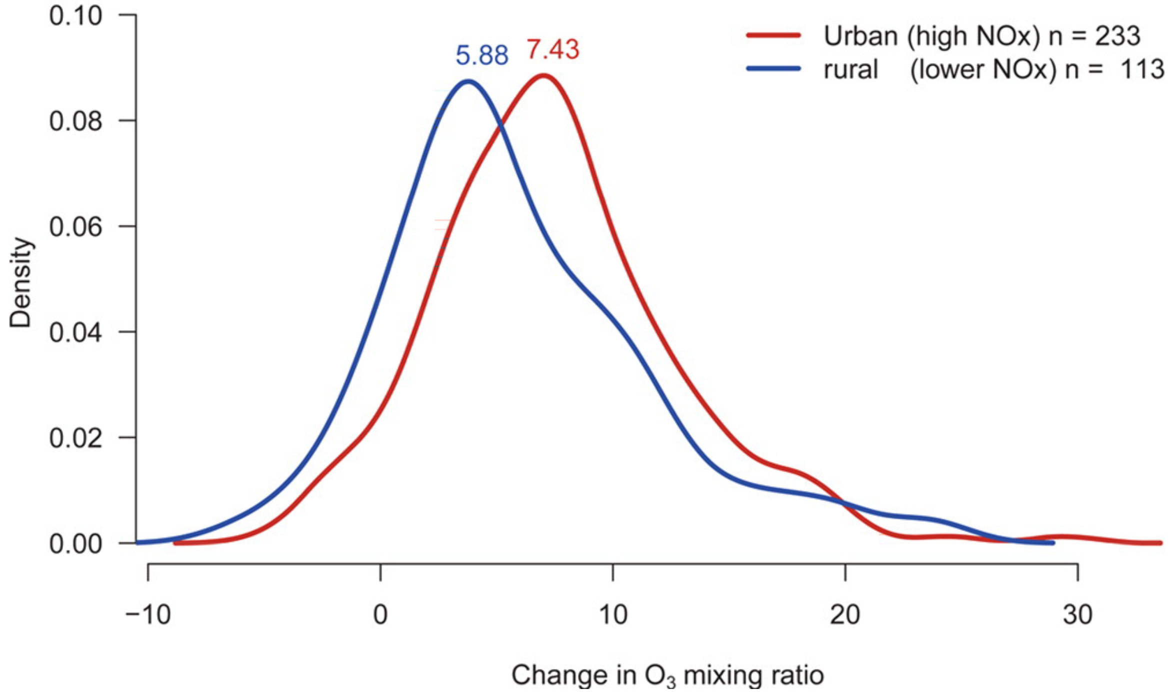
Mixing of smoke organics with fresh NO_x from the fires can increase urban O_3 formation

Alvarado et al., Smoke Chemistry, in Peterson, D. L., McCaffrey, S. M., & Patel-Weynand, T. (2022). Wildland Fire Smoke in the United States: A Scientific Assessment (p. 341). Springer Nature.



Estimates of the increase in O_3 when smoke mixes with urban emissions (Brey and Fischer, ES&T) 2016



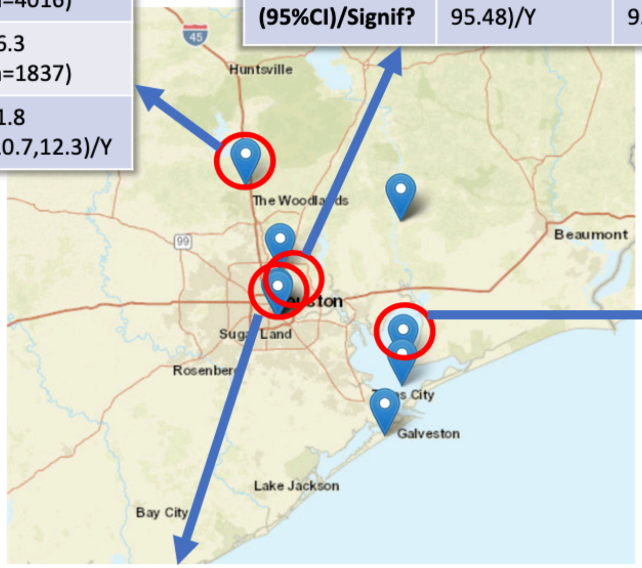


Our Previous Work on Smoke Influences on O_3 in Houston

Impacts of 8-20 ppbv O_3!

LAUNCH TRAILER	CO (ppbv)	O_3 (ppbv)	NO (ppbv)	NO_2 (ppbv)	NOy (ppbv)
Mean (HMS Smoke)	295.5 (n=3151)	30.39 (n=4016)	4.421 (n=3947)	16.14 (n=3468)	17.38 (n=3979)
Mean (HMS No smoke)	207.0 (n=1141)	21.57 (n=1823)	2.373 (n=1759)	9.607 (n=1575)	9.743 (n=1832)
Diff (95%CI)/Signif?	88.49 (81.51, 95.48)/Y	8.811 (7.886, 9.735)/Y	2.049 (1.695, 2.402)/Y	6.537(5.890, 7.184)/Y	7.643 (7.028, 8.257)/Y

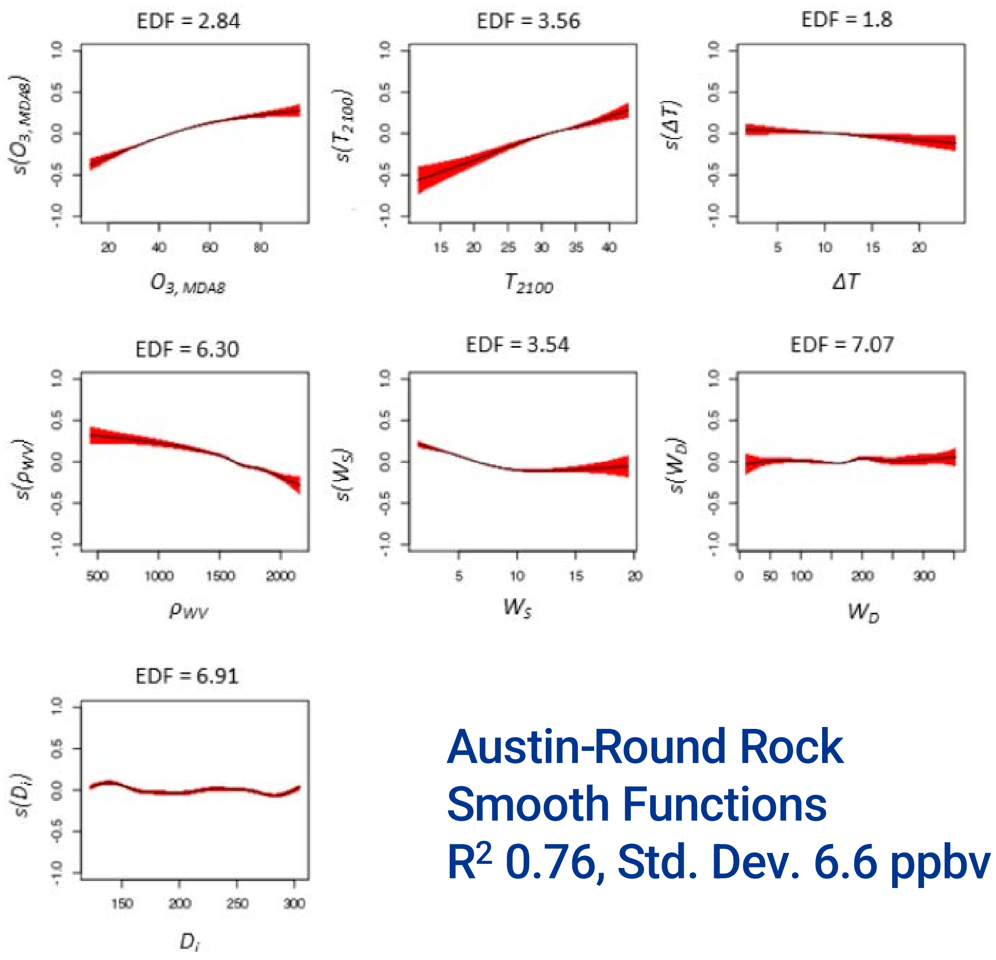
JONES FOREST	CO (ppbv)	O3 (ppbv)
Mean (HMS Smoke)	197.8 (n=2782)	38.1 (n=4016)
Mean (HMS No smoke)	135.4 (n=839)	26.3 (n=1837)
Diff (95%CI)/Signif?	62.4 (59.1,65.8)/Y	11.8 (10.7,12.3)/Y



SMITH POINT	O_3 (ppbv)	NO (ppbv)	NO_2 (ppbv)
Mean (HMS Smoke)	42.2 (n=3071)	0.400 (n=2660)	3.21 (n=2647)
Mean (HMS No smoke)	21.3 (n=1084)	0.566 (n=1088)	2.12 (n=1084)
Diff (95%CI)/Signif?	20.9 (20.3, 21.6)/Y	-0.167 (-0.372, 0.0400)/N	1.09 (0.844, 1.33)/Y

MOODY TOWER	CO (ppbv)	O_3 (ppbv)	NO (ppbv)	NO_2 (ppbv)	NOy (ppbv)	SO_2 (ppbv)
Mean (HMS Smoke)	219.9 (n=3153)	34.35 (n=4045)	3.138 (n=4003)	11.19 (n=4004)	15.97 (n=4003)	0.7899 (n=3360)
Mean (HMS No smoke)	154.3 (n=1651)	21.95 (n=1984)	1.364 (n=1994)	5.724 (n=1995)	8.100 (n=1995)	0.2883 (n=1631)
Diff (95%CI)/Signif?	65.60 (60.54, 70.66)/Y	12.40 (11.52, 13.28)/Y	1.774 (1.498, 2.051)/Y	5.470(5.091, 5.849)/Y	7.872(7.315, 8.429)/Y	0.5017(0.4354, 0.5680)/Y

Our Previous Statistical Studies of O_3 Formation in Texas



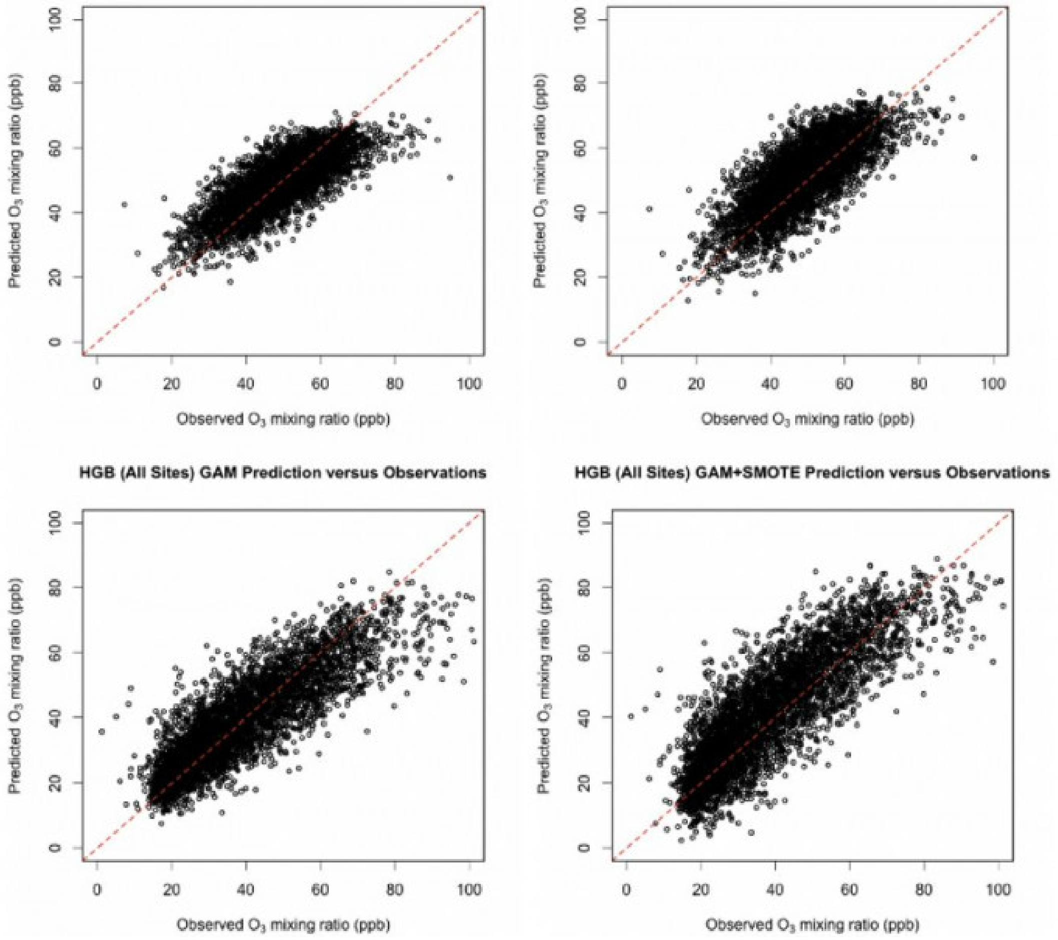
Austin-Round Rock
Smooth Functions
R^2 0.76, Std. Dev. 6.6 ppbv

Pernak et al., AAQR, 2019.
https://doi.org/10.4209/aaqr.2018.12.0464

Original | With Synthetic Data

El Paso

Houston



Brown-Steiner et al., AAQR, 2021.
https://doi.org/10.4209/aaqr.210077

Objectives

1. Use generalized additive models (GAMs) driven with satellite and surface observations to examine the impact of fires on background and total O_3 and $PM_{2.5}$ in two Texas urban areas (Houston and El Paso).

2. Examine the ability of CAMx photochemical model to simulate these fire impacts by applying similar statistical methods to the CAMx results.

3. Use any statistically significant differences found to prioritize different approaches to improve the ability of CAMx to simulate the impacts of domestic fires on air quality.

Ambient Air Quality Data

- Surface air quality data from TAMIS
- Calculated maximum daily 8-hour average (MDA8) O_3 mixing ratios and daily average $PM_{2.5}$ concentrations for each site
  - Sites separated into background (for sites on the outskirts of the city) and urban (for sites near the city core).
  - Background: the minimum value of MDA8 O_3 and daily average $PM_{2.5}$ from background sites
  - Maximum: Maximum concentrations in each region (including background sites).

Meteorological Predictors

1. Afternoon mean temperature (°C, *afternoon_mean_T*, 1-4 PM CST)
2. Diurnal temperature change (°C, *diurnal_T*)
3. Daily average wind speed (m/s, *daily_ws*)
4. Daily average wind direction (degrees clockwise from North, *daily_wd*)
5. Daily average water vapor density (g/m^3, *SWVP*)
6. Morning surface temperature difference (1200 UTC) (temperature at 925 or 700 mb−temperature at surface at 1200 UTC) (°C, *T_dif_925mb* or *T_dif_700mb*)
7. Transport direction (degrees clockwise from North, *HYSPLIT_Bearing*)
8. Transport distance (m, *HYSPLIT_dist*)

Variables 1-5 were calculated from the surface meteorological data in the Texas Air Monitoring Information System (TAMIS).

Variable 6 was calculated from the the Integrated Global Radiosonde Archive (IGRA Version 2).

Variables 7 and 8 were calculated from 24-hour HYSPLIT back-trajectories (300 m AGL, start at local solar noon) driven with 12 km NAM data.

Fire and Smoke Predictors: NOAA HMS Smoke Flag

The smoke flag files were generated from NOAA Hazard Mapping System (HMS) smoke polygons for 2012 – 2021 that were converted to the GOES CONUS grid for colocation with the urban area.

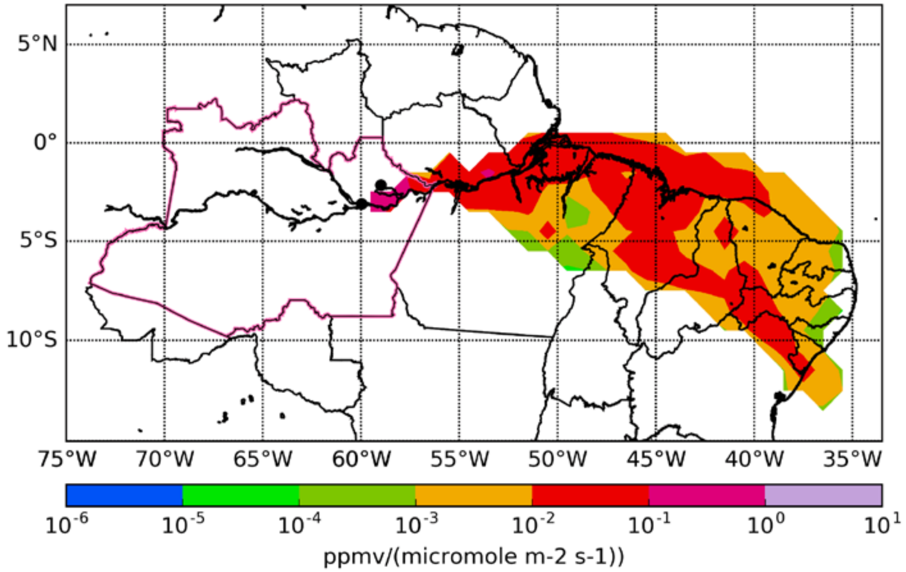
Fire and Smoke Predictors: FINN Fire Counts and Emissions

- **Large-scale**
  - Used Fire Inventory from NCAR (FINN v2.5, Wiedinmyer et al., 2011, McDonald-Buller et al., 2015, 1 km resolution)
  - Determined fire counts within different distances from the city center (0.5, 1.0, 2.5, 5.0, 10.0, and 25.0 degrees (lat/lon) from the city).

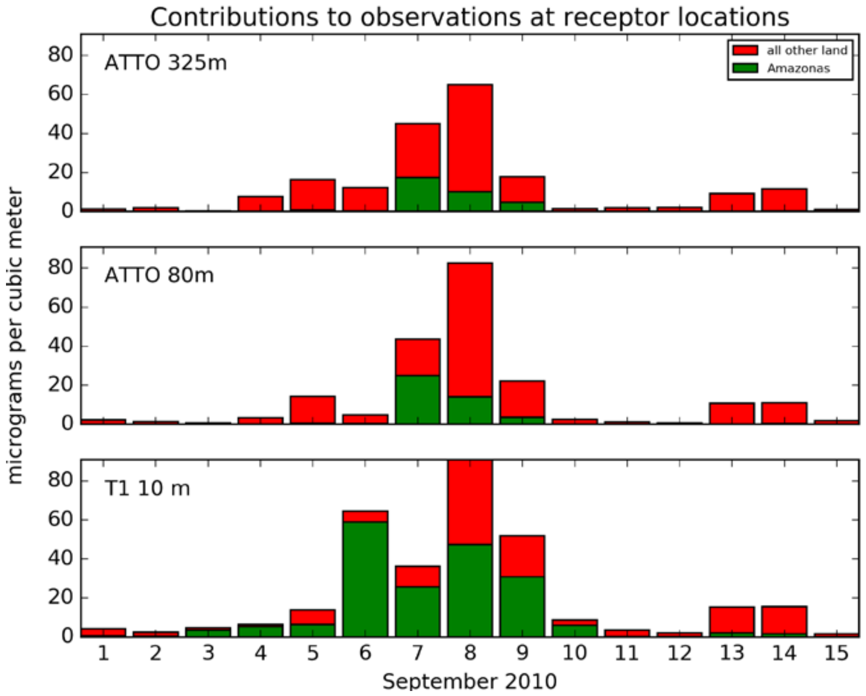
- **Geographic**
  - Sum fire counts, area, biomass burned, and species emissions for Mexico (MEX), Yucatan (YUCATAN), states bordering Texas (NM, AR, OK, LA) and California (CA)

Fire and Smoke Predictors: WRF-STILT Footprints

WRF-STILT traces 500 stochastic particle back-trajectories to determine the sensitivity of observed concentrations to emissions upwind (i.e., the footprint, left).



Accumulated "footprint" estimating impact of fire emissions on $PM_{2.5}$ concentrations at Manaus.



Modeled fire $PM_{2.5}$ levels at different locations and heights in Manaus in Sept. 2010. Green is from fires in Amazonas, red from all other fires.

Convolved 3-day WRF-STILT footprints with 0.1x0.1 degree FINN v2.5 fire emissions for NO, NO_2, CO, and CO_2 to get estimates of fire emissions impact.

Results were very similar regardless of species, so focused on NO.

CAMx Data

- TCEQ generated CAMx output for the Houston (4 km horizontal resolution) and El Paso (12 km resolution) for the year 2019 was used for the comparison with observed data.

- MDA8 O_3 values were calculated for each monitoring location based on the CAMx grid box that contained the monitoring location.

- New CAMx-based values for the maximum MDA8 O_3 and background MDA8 O_3 value for each urban area by date were calculated using the same methods used for the ambient data.

Generalized Additive Models

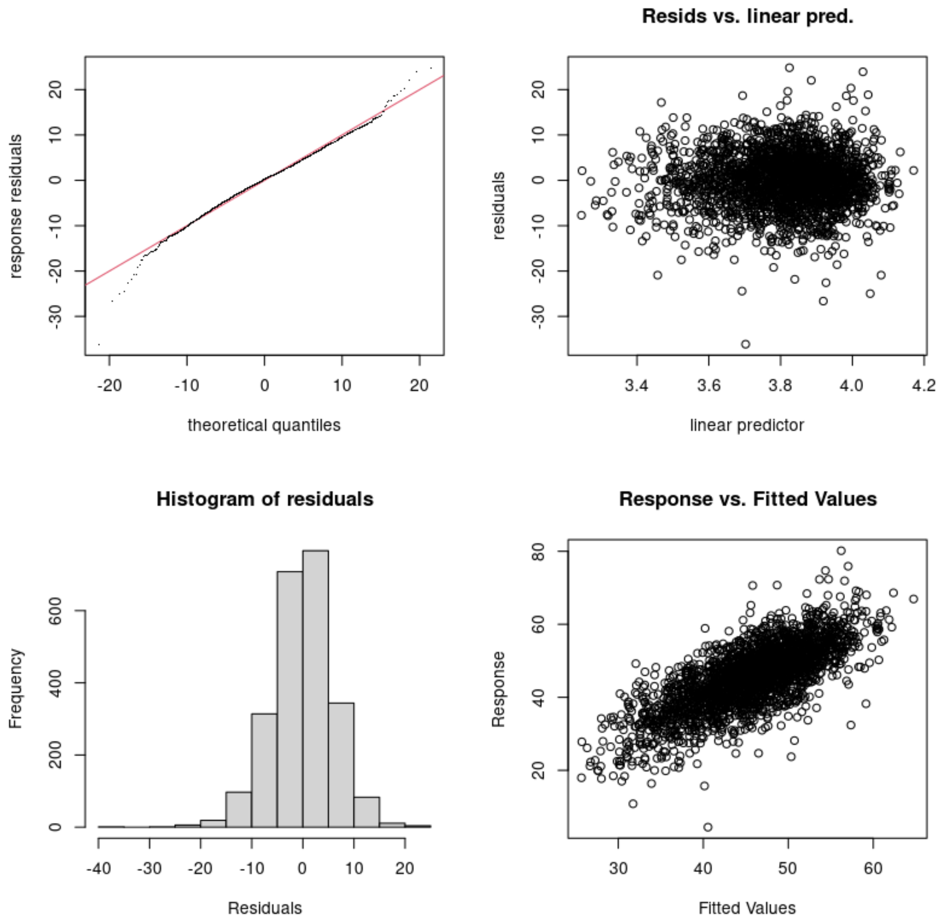
- GAMs are extensions of multiple linear regression models that fit unknown non-linear functions of predictors

$$g(\mu_i) = \beta_o + f_1(x_{i,1}) + f_2(x_{i,2}) + \cdots f_n(x_{i,n}) + f_p(D_i) + W_d$$

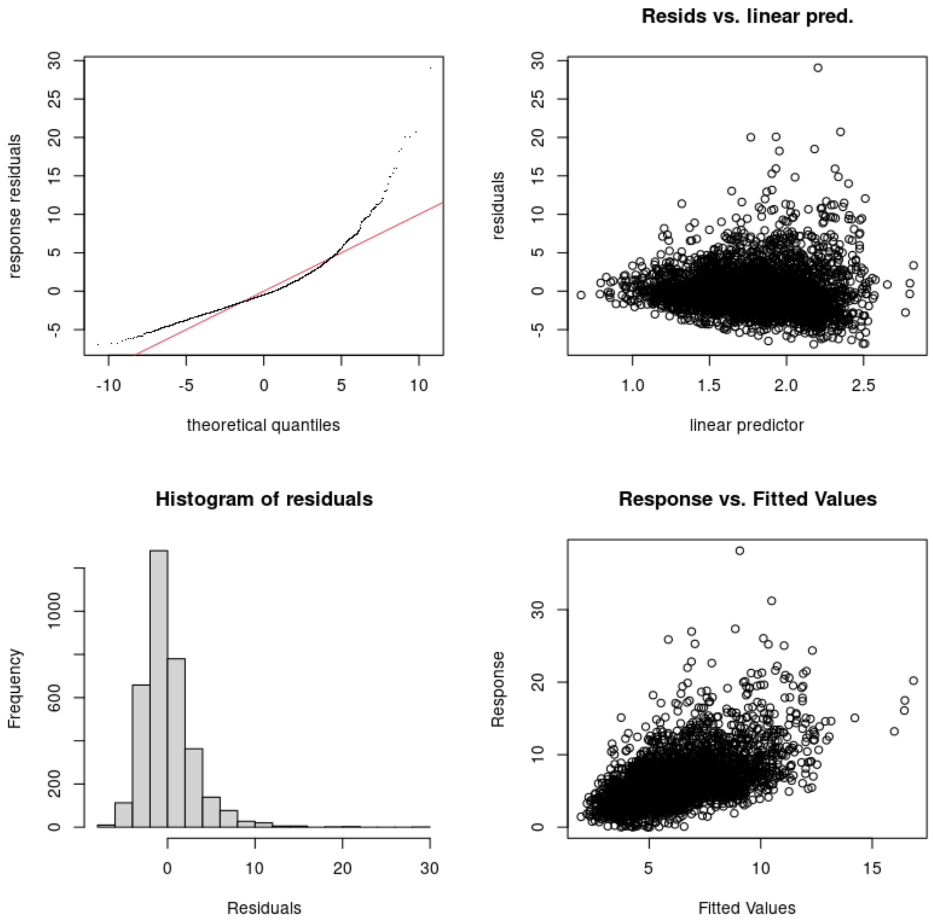
- The R package *mgcv* includes routines to fit GAMs, examine the models graphically, and test their robustness via k-fold cross-validation and other techniques.
- In this study, all meteorological and fire predictors (except HMS smoke flag) were simulated as smooth functions using cubic spline basis set, with periodic splines used to account for the effects of the day of year and HYSPLIT bearing.
- Year, day of week, and the HMS smoke flag were included as factor variables.
- The models predict the natural logarithm of O_3 and $PM_{2.5}$ concentrations as these are usually log-normally distributed.

Checking Quality of Fit

Good Fit, El Paso O_3



Poor Fit, Houston $PM_{2.5}$



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Objective 1: Impact of fires on urban AQ in Texas

Smoke Flag Tests: MDA8 O_3 Impacts

	Houston MDA8 O_3		El Paso MDA8 O_3	
	Bkgrd (ppbv)	Max (ppbv)	Bkgrd (ppbv)	Max (ppbv)
Minimum	1.2	1.5	1.7	1.4
25th Percentile	1.9	2.1	2.2	1.8
Median	2.3	2.5	2.4	1.9
Mean	2.4	2.6	2.4	1.9
75th percentile	2.8	3.0	2.5	2.0
Max	4.7	4.8	2.9	2.4
Std. Dev.	0.6	0.6	0.2	0.2

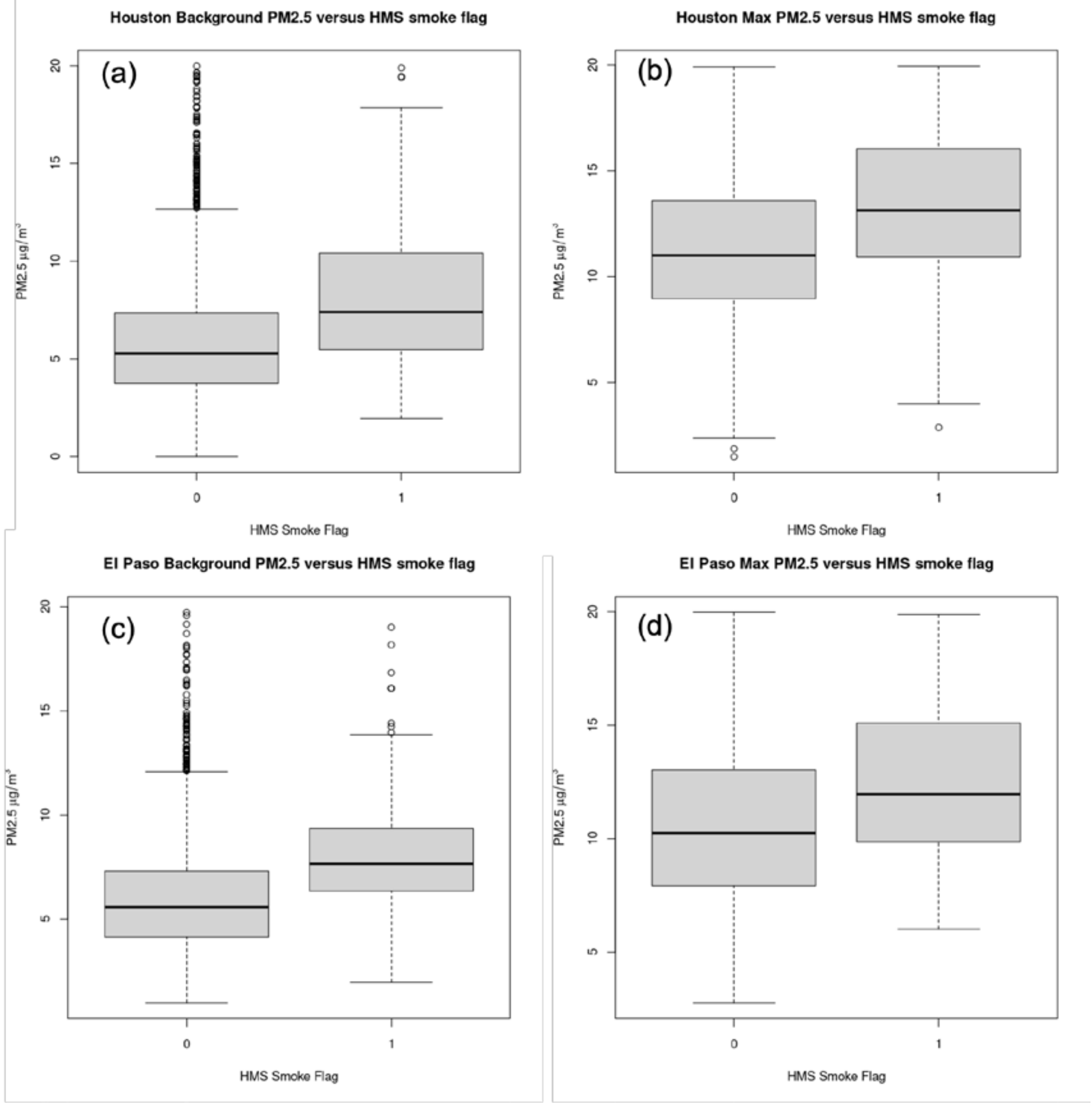
- O_3 is increased by 1.2-4.8 ppbv when HMS says there is smoke over the city
- Less than impact of smoke inferred when not controlling for meteorology.
- Small increase in impact when smoke enters Houston, small decrease in El Paso

Smoke Flag Tests: Daily Average $PM_{2.5}$ Impacts

Background | Maximum

Houston

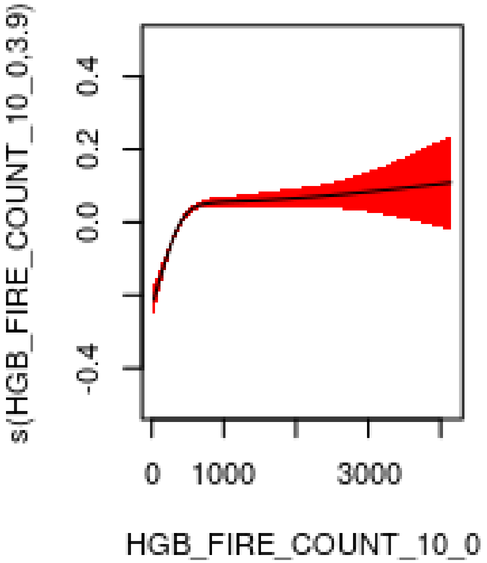
El Paso

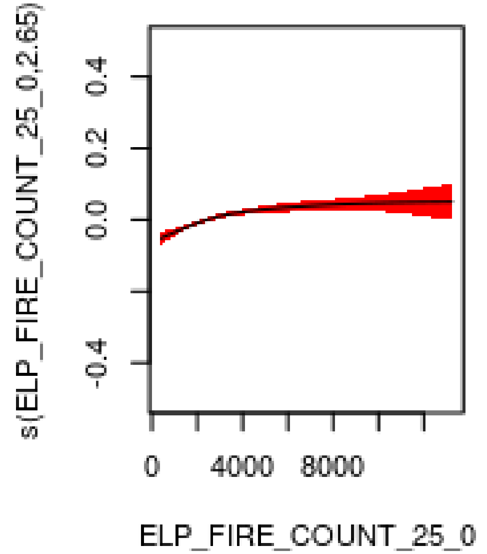


- Houston $PM_{2.5}$ Background: 1.9-2.6 µg/m³
- Houston $PM_{2.5}$ Max: 1.5-2.3 µg/m³
- El Paso $PM_{2.5}$ Background: 1.7-2.5 µg/m³
- El Paso $PM_{2.5}$ Max: 1.5-2.6 µg/m³

FINN Large-Scale Fire Count Tests: Max O_3 Fits

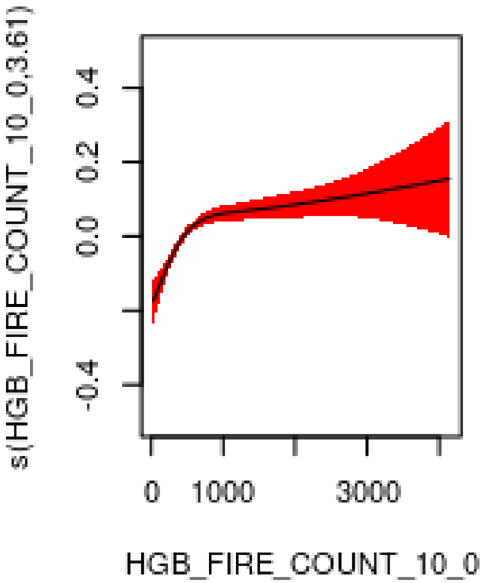
	Houston Max MDA8 O_3			El Paso Max MDA8 O_3		
	Dev. Exp. (%)	GCV	p	Dev. Exp. (%)	GCV	p
0.5 degrees	67.5	83.019	<0.001	53.9	46.927	0.75
1.0 degrees	67.7	82.492	<0.001	53.9	46.899	0.21
2.5 degrees	68.4	80.655	<0.001	54.1	46.741	<0.01
5.0 degrees	68.7	79.895	<0.001	54.2	46.608	<0.001
10 degrees	**69.0**	**79.214**	**<0.001**	54.1	46.859	0.08
25 degrees	67.5	82.795	<0.001	**54.9**	**45.988**	**<0.001**
Best + HMS smoke flag	69.1	79.025	<0.001	55.1	45.959	<0.001

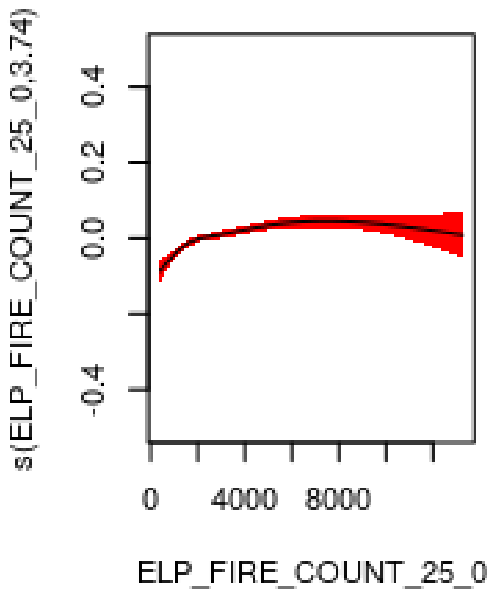




FINN Large-Scale Fire Count Tests: Bkgrd O_3 Fits

	Houston Bkgrd MDA8 O_3			El Paso Bkgrd MDA8 O_3		
	Dev. Exp. (%)	GCV	p	Dev. Exp. (%)	GCV	p
0.5 degrees	63.5	60.402	0.05	51.0	40.737	0.76
1.0 degrees	63.7	60.14	0.001	51.0	40.739	0.69
2.5 degrees	64.1	59.389	<0.001	51.2	40.619	0.01
5.0 degrees	64.4	58.959	<0.001	51.2	40.621	0.04
10 degrees	**64.4**	**59.072**	**<0.001**	51.3	40.619	0.01
25 degrees	64.0	59.671	<0.001	**52.3**	**39.788**	**<0.001**
Best + HMS smoke flag	64.6	58.890	<0.001	52.6	39.641	<0.001





FINN Large-Scale Fire Count Tests: MDA8 O_3 Impacts

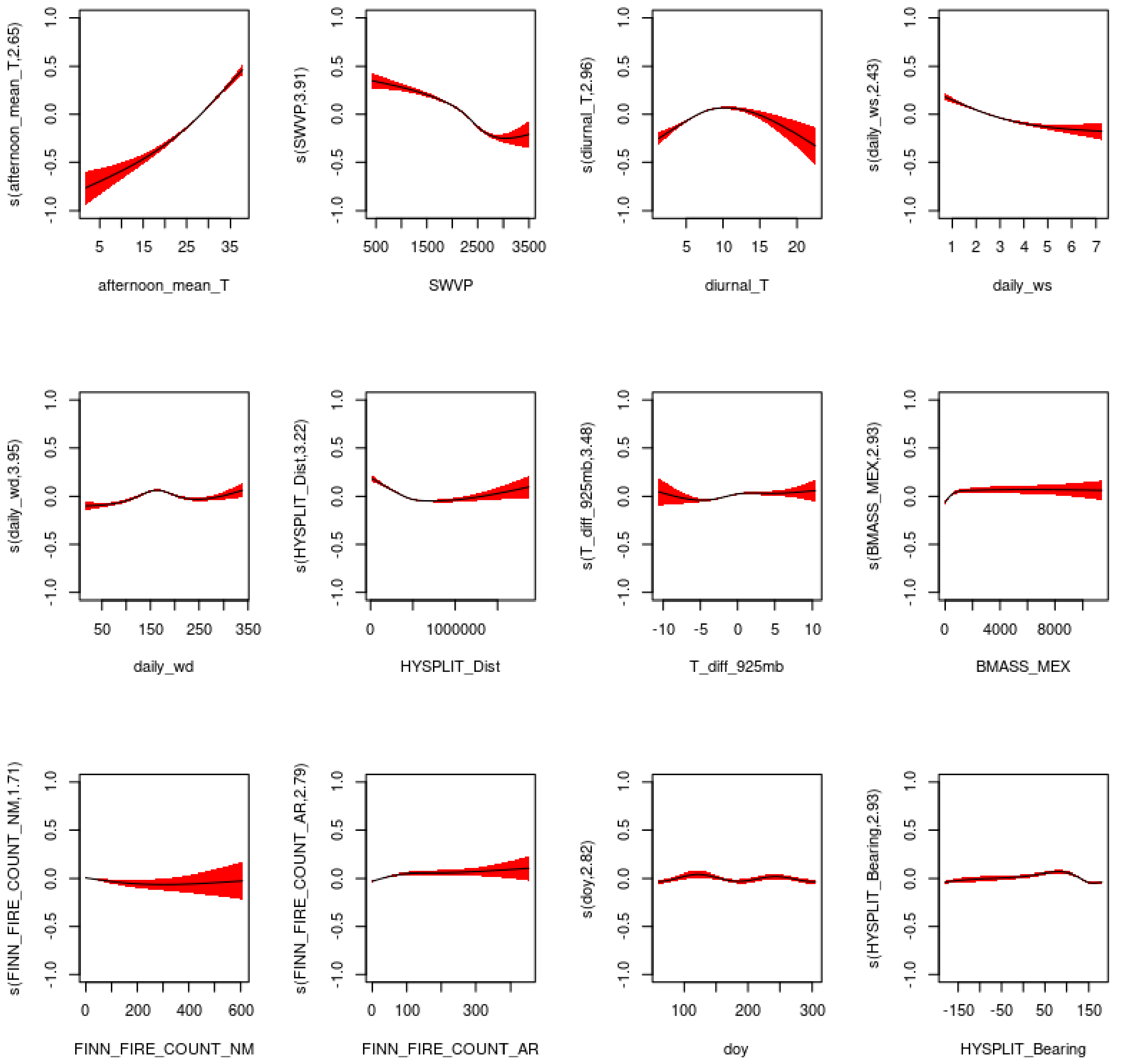
	Houston MDA8 O_3		El Paso MDA8 O_3	
	Bkgrd (ppbv)	Max (ppbv)	Bkgrd (ppbv)	Max (ppbv)
Minimum	1.3	2.4	2.7	1.9
25th Percentile	5.8	11.3	5.3	3.3
Median	7.9	13.6	6.1	4.3
Mean	7.8	13.8	6.1	4.5
75th percentile	9.6	16.9	6.9	5.7
Max	18.4	28.2	9.4	8.8
Std. Dev.	3.0	4.3	1.4	1.4

- Adding FINN fire counts greatly increases the estimated impact of smoke on O_3, more in line with uncorrected BC2 estimates from previous work
- Large increase in impact when smoke enters Houston, small decrease in El Paso

FINN Geographic Predictor Tests: Best variables

Region	Houston		El Paso	
	Maximum MDA8 O_3	Background MDA8 O_3	Maximum MDA8 O_3	Background MDA8 O_3
MEX	Biomass burned (BMASS)	Non-methane hydrocarbon (NMHC) emissions	BMASS	Xylene emissions
YUC	Fire Area	Fire Count	Fire Area	Fire Area
OK	Fire Count	BMASS	Fire Count	Fire Count
NM	Fire Count	Fire Count	Fire Count	Fire Count
LA	Fire Count	Fire Count	Hydroxyacetone (HYAC) emissions	CH_3CN emissions
AR	Fire Count	NMHC emissions	Fire Count	Fire Count
CA	NO_x emissions as NO	Glycoladehyde (GLYALD) emissions	NO_x emissions as NO	Fire Area

Houston Maximum O_3

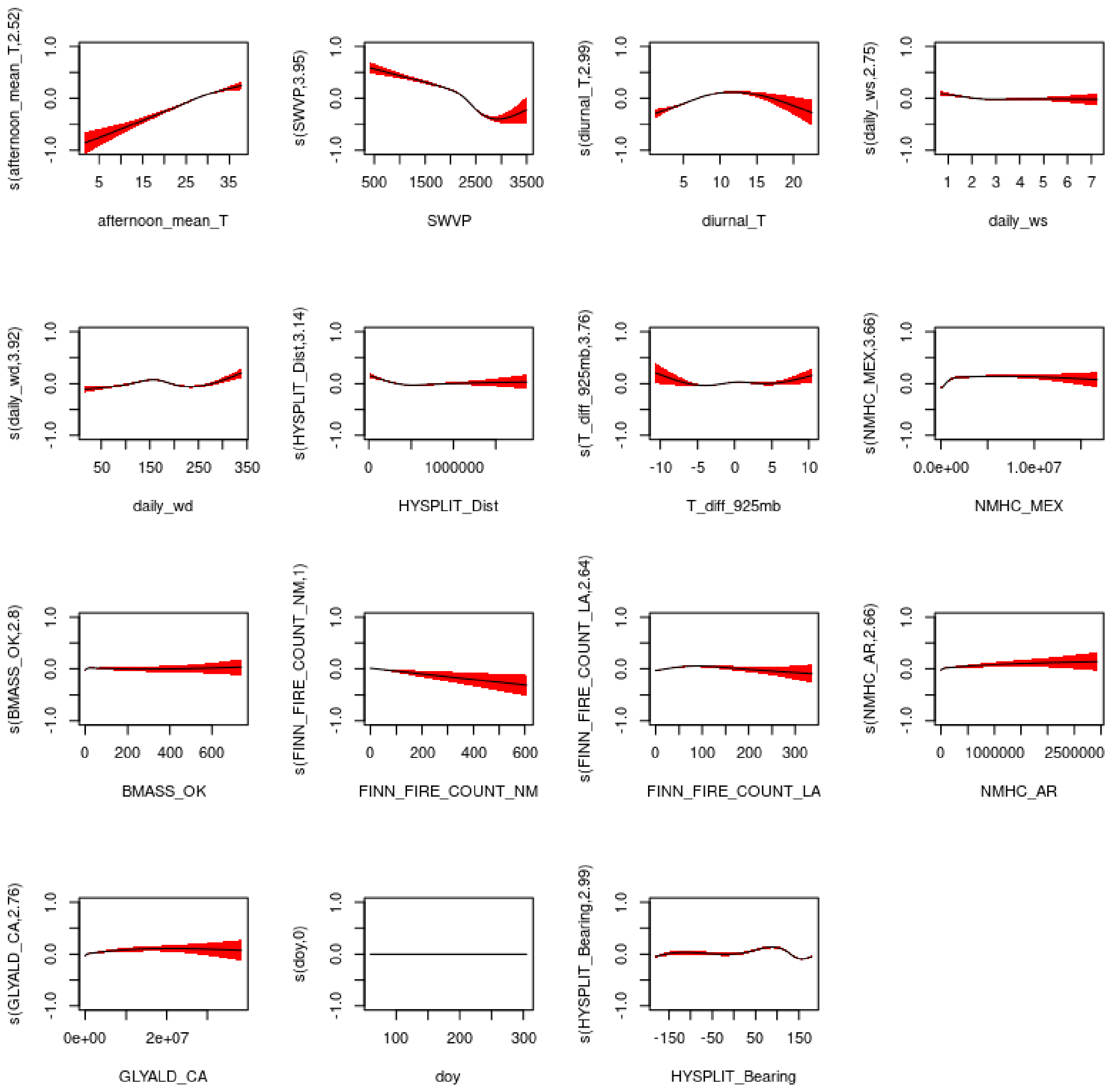


Only MEX, AR, and NM kept as significant predictors.

Total deviance explained was 68.2% with a GCV of 81.6, which is a better fit than the large-scale FINN fire counts.

Increases in Mexican biomass burned and Arkansas fire counts were associated with increased O3 but saturated at relatively low values, while NM fire counts slightly decreased O_3

Houston Background O_3

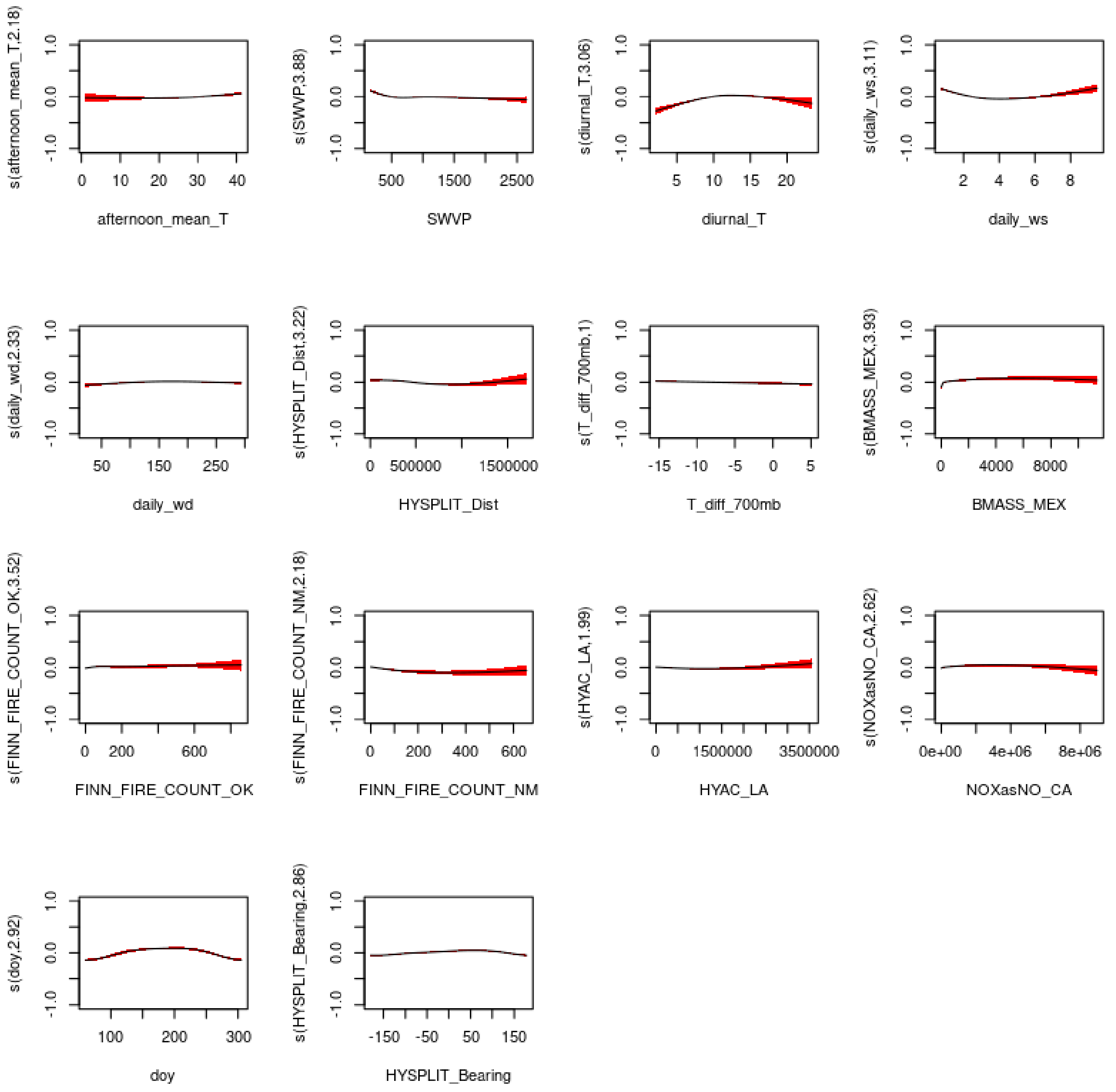


All variables were kept as significant predictors.

Total deviance explained was 65.5% with a GCV of 57.9, which is a better fit than the large-scale FINN fire count fit.

All fire impacts were positive except for NM, with MEX and AR showing the largest impacts (Figure 4).

El Paso Maximum O_3

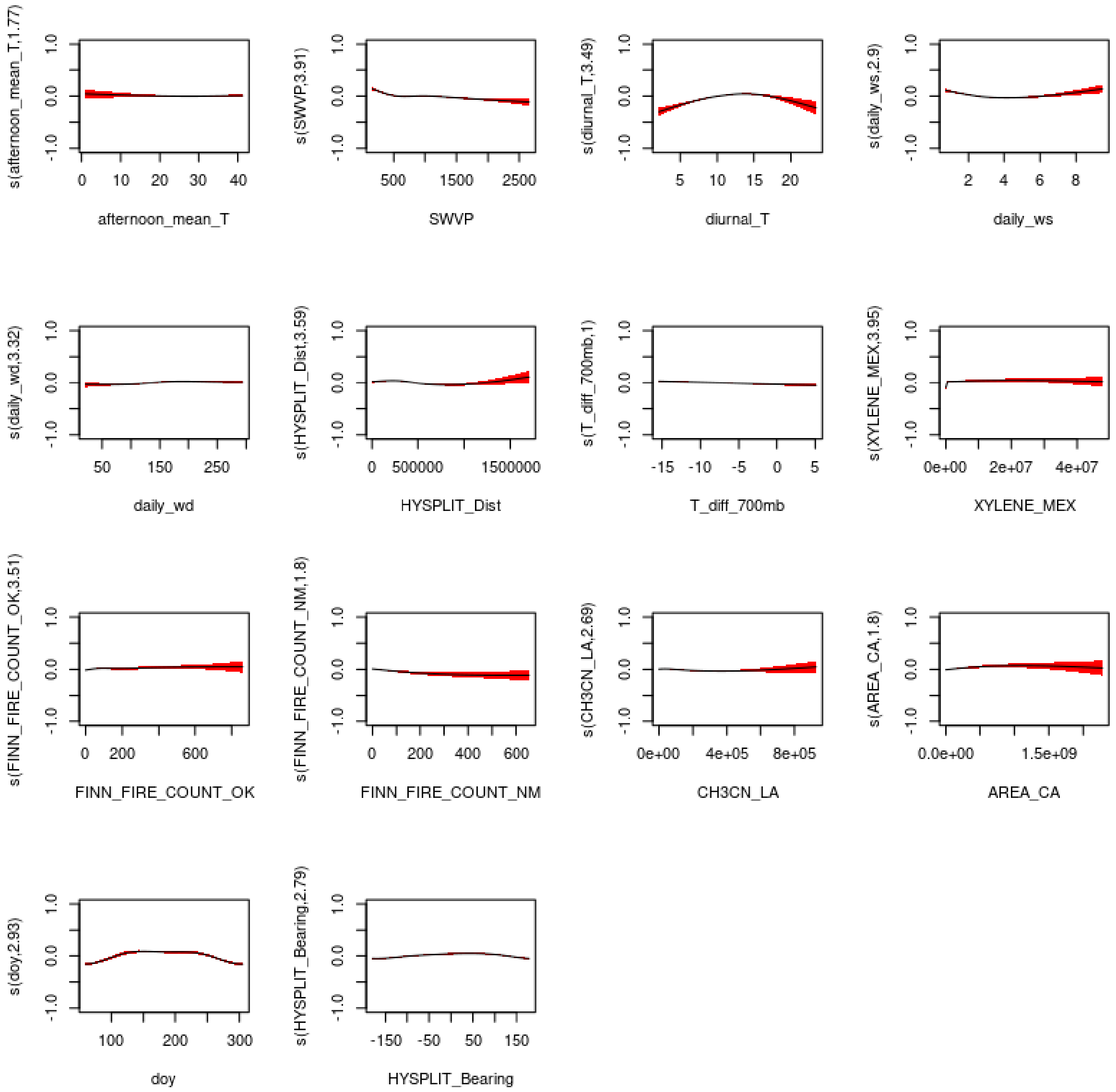


AR was removed, but all other variables kept as significant predictors.

Total deviance explained was 57.1% with a GCV of 44.43, which is a better fit than the large-scale FINN fire count.

Only the Mexico predictor had a large increase in O_3 and saturated quickly.

El Paso Background O_3



AR was removed, but all other variables kept as significant predictors.

Total deviance explained was 54.4% with a GCV of 38.57, which is a better fit than the large-scale FINN fire count fit from Section 4.1.2.

Mexico tended to increase O_3 while NM decreased it.

FINN Geographic Variables

	Houston MDA8 O_3		El Paso MDA8 O_3	
	Bkgrd (ppbv)	Max (ppbv)	Bkgrd (ppbv)	Max (ppbv)
Minimum	1.0	2.0	1.6	0.3
25th Percentile	5.6	5.3	5.5	5.4
Median	7.7	7.0	7.4	7.2
Mean	8.0	7.1	7.2	7.0
75th percentile	9.8	8.4	8.7	8.5
Max	23.2	20.5	13.0	12.6
Std. Dev.	3.7	2.8	2.1	2.3

- Gives best fit with data of tested predictors
- Significant smoke impacts (mean 7-8 ppbv)
- **Small decrease** in impact when smoke enters Houston, small decrease in El Paso

WRF-STILT Footprint Tests

- The convolved footprints were highly significant predictors ($p \ll 0.001$) in Houston, but surprisingly were not significant predictors for El Paso.

- The deviance explained and GCV statistics for each fit were:
  - Houston Maximum – Deviance explained 67.9%, GCV 81.9
  - Houston Background – Deviance explained 64.2%, GCV 59.4
  - El Paso Maximum – Deviance explained 54.2%, GCV 46.1
  - El Paso Background – Deviance explained 51.8%, GCV 39.8

- These fit statistics are generally worse than those using the FINN fire count variables, suggesting that the WRF-STILT footprints may not correctly represent the transport of biomass burning emissions to these urban areas.

WRF-STILT Footprint Tests

	Houston MDA8 O_3		El Paso MDA8 O_3	
	Bkgrd (ppbv)	Max (ppbv)	Bkgrd (ppbv)	Max (ppbv)
Minimum	-2.9	1.2	1.6	1.2
25th Percentile	3.4	5.4	2.3	1.7
Median	4.7	6.6	2.6	1.9
Mean	4.5	6.7	2.7	2.0
75th percentile	5.8	8.3	3.1	2.1
Max	10.22	13.3	4.7	5.8
Std. Dev.	1.9	2.4	0.6	0.6

- Lower impacts than FINN fits, but poorer fit
- Shape of response similar to Mexican FINN variables
- Significant smoke impacts (mean 7-8 ppbv)
- Large increase in impact when smoke enters Houston, small decrease in El Paso

Ambient Fit Summary

	Houston MDA8 O_3		El Paso MDA8 O_3	
	Bkgrd (ppbv)	Max (ppbv)	Bkgrd (ppbv)	Max (ppbv)
Smoke flag only	2.4	2.6	2.4	1.9
+ large-scale fire counts	7.8	13.8	6.1	4.5
+ geographic fire variables	8.0	7.1	7.2	7.0
+ WRF-STILT footprints	4.5	6.7	2.7	2.0

- Houston
  - Mean background MDA8 O_3 is increased 2.4 to 8.0 ppbv by smoke
  - Change in O_3 impact as the smoke enters the city -0.9 ppbv to +6.0 ppbv
- El Paso
  - Mean background MDA8 O_3 is increased 2.4 to 7.2 ppbv by smoke
  - Change in O_3 impact as the smoke enters the city -1.6 ppbv to -0.5 ppbv.

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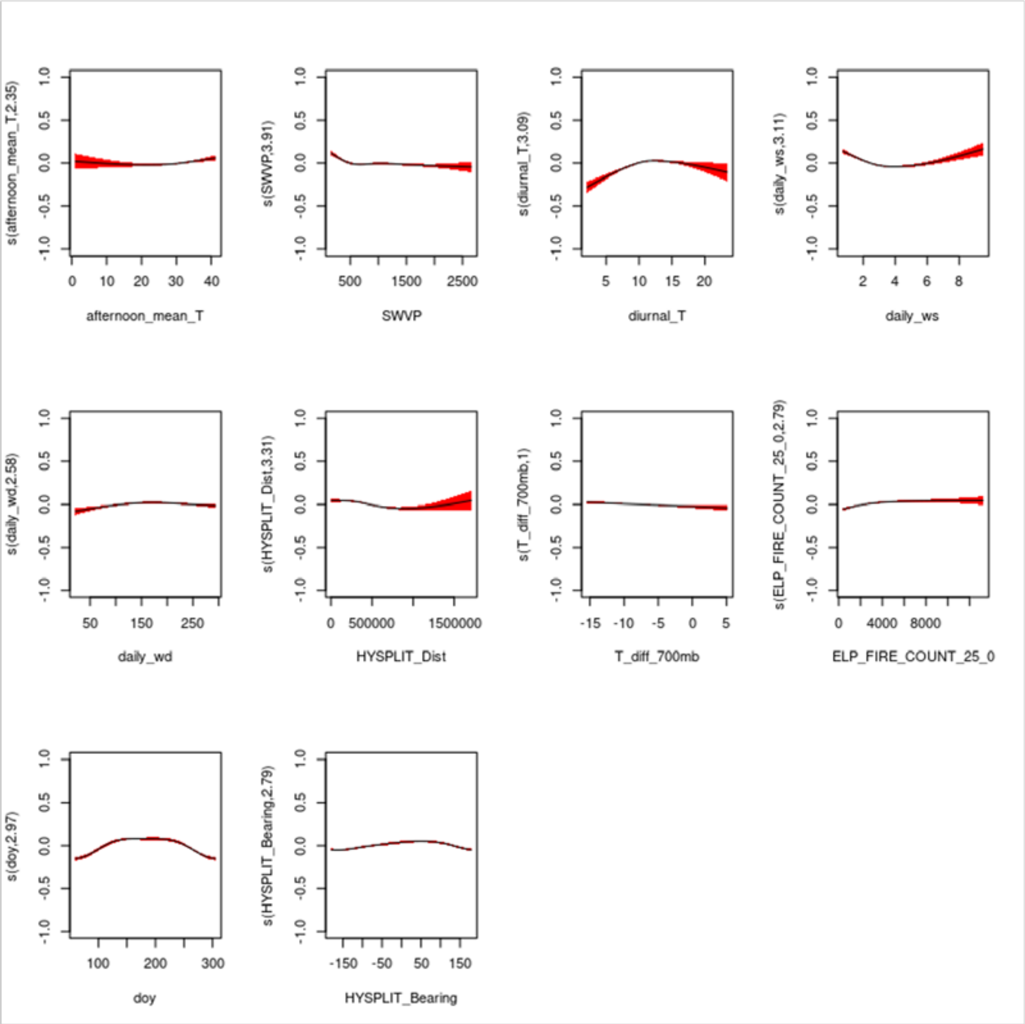
Objective 2: Ability of CAMx to simulate fire impacts

Methods

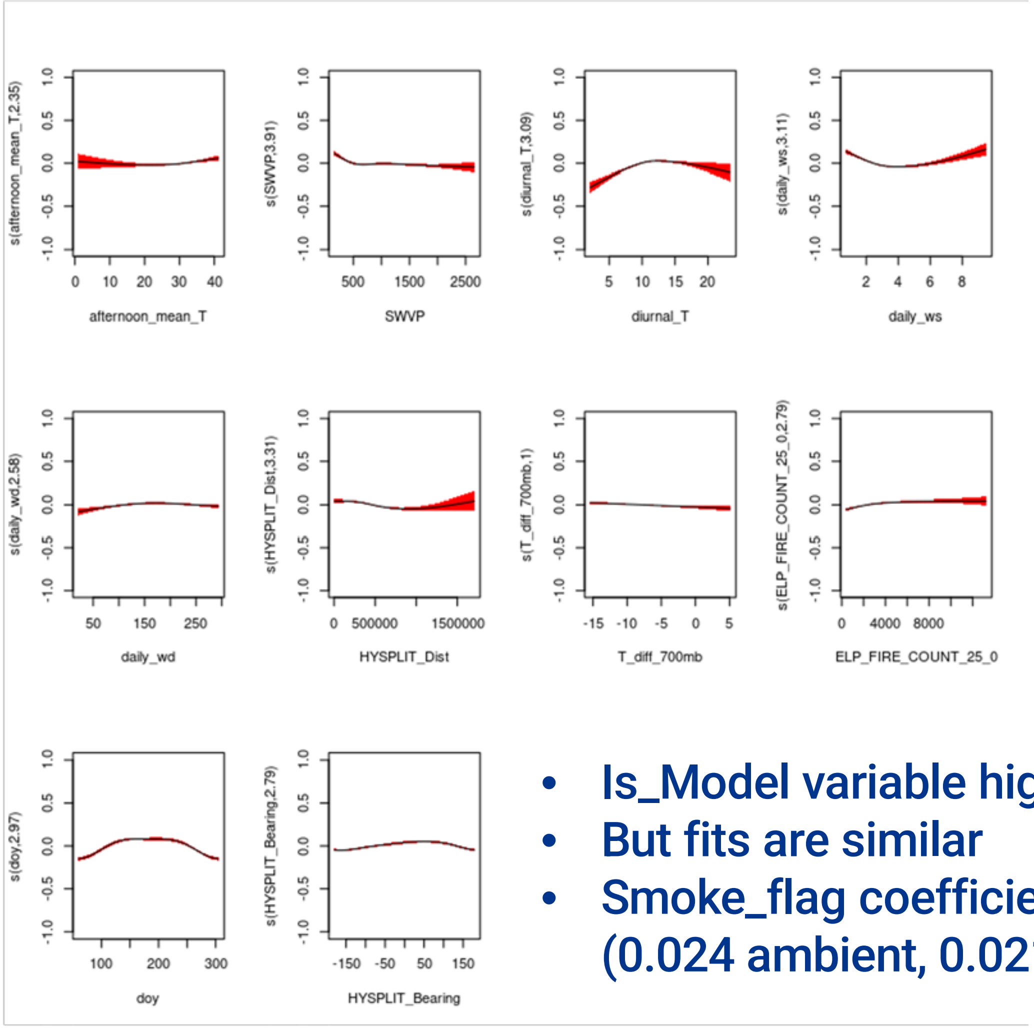
- Use the FINN large scale predictors and the smoke flag
  - Houston: FINN fire counts within 10 degrees
  - El Paso: FINN fire counts within 25 degrees
- Include Is_Model variable in the fit as a factor
- If Is_Model is statistically significant, the CAMx simulation is different from the ambient data
- Determine source of difference
  - Examine smooth fits and factor coefficients for differences
  - Look at difference in GAM predictions for 2019 for different O_3 levels
  - Look at differences in predicted smoke impacts

El Paso Maximum MDA8 O_3

(a) Ambient



(b) With CAMx



- Is_Model variable highly significant
- But fits are similar
- Smoke_flag coefficients similar (0.024 ambient, 0.021 CAMx)

El Paso Maximum MDA8 O_3: Total O_3 Predictions

	Ambient (ppbv) (Is_Model = 0)	CAMx (ppbv) (Is_Model = 1)	% Difference
Minimum	35.3	34.1	-3%
25th Percentile	47.7	44.5	-7%
Median	53.4	49.7	-7%
Mean	52.7	48.7	-8%
75th percentile	57.8	53.1	-8%
Max	68.4	61.8	-10%
Std. Dev.	6.9	5.9	

- CAMx underestimates maximum O_3 in El Paso, with underestimates more severe at high O_3 levels

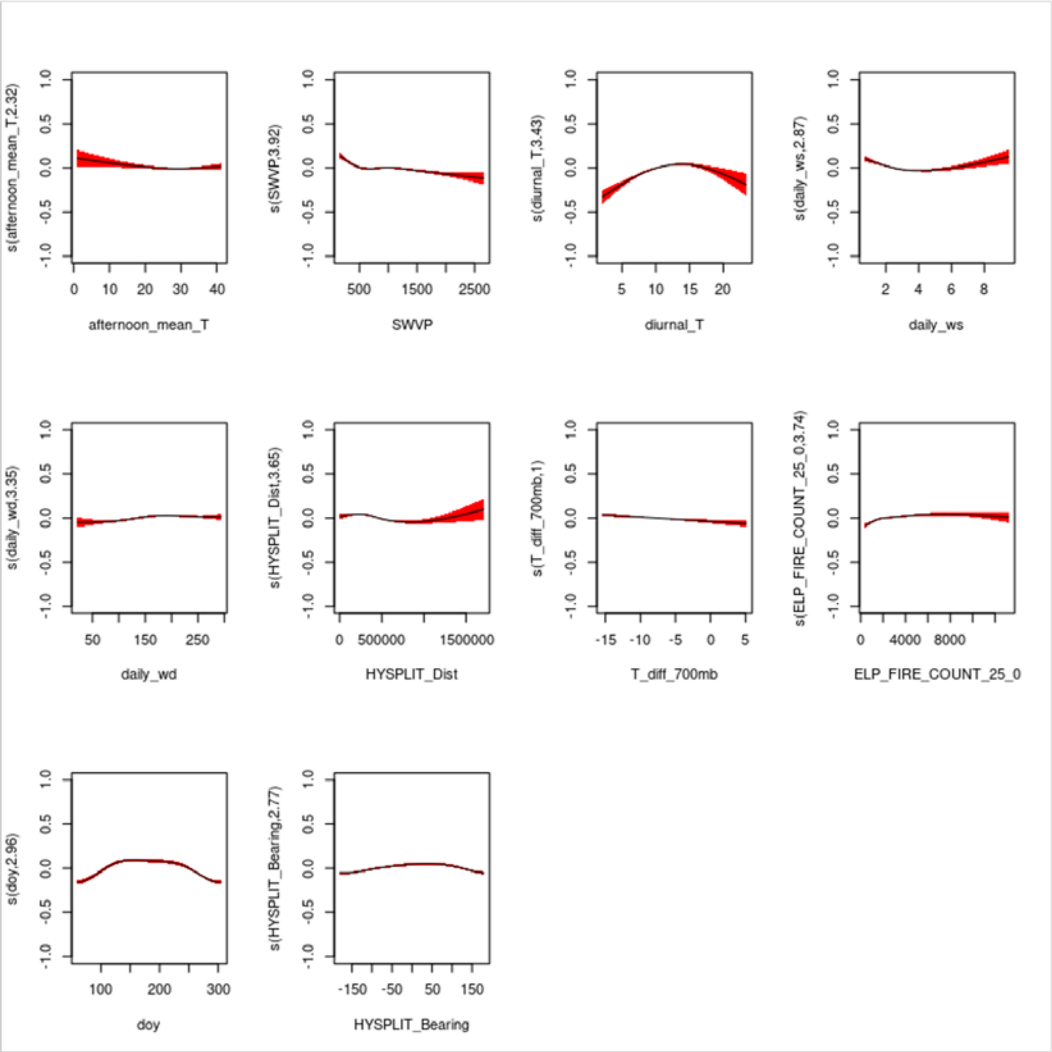
El Paso Maximum MDA8 O_3: Smoke O_3 Predictions

	Ambient (ppbv)	CAMx (ppbv)
Minimum	2.8	2.5
25th Percentile	4.0	3.7
Median	4.2	3.9
Mean	4.3	4.0
75th percentile	4.7	4.4
Max	5.6	5.2
Std. Dev.	0.8	0.8

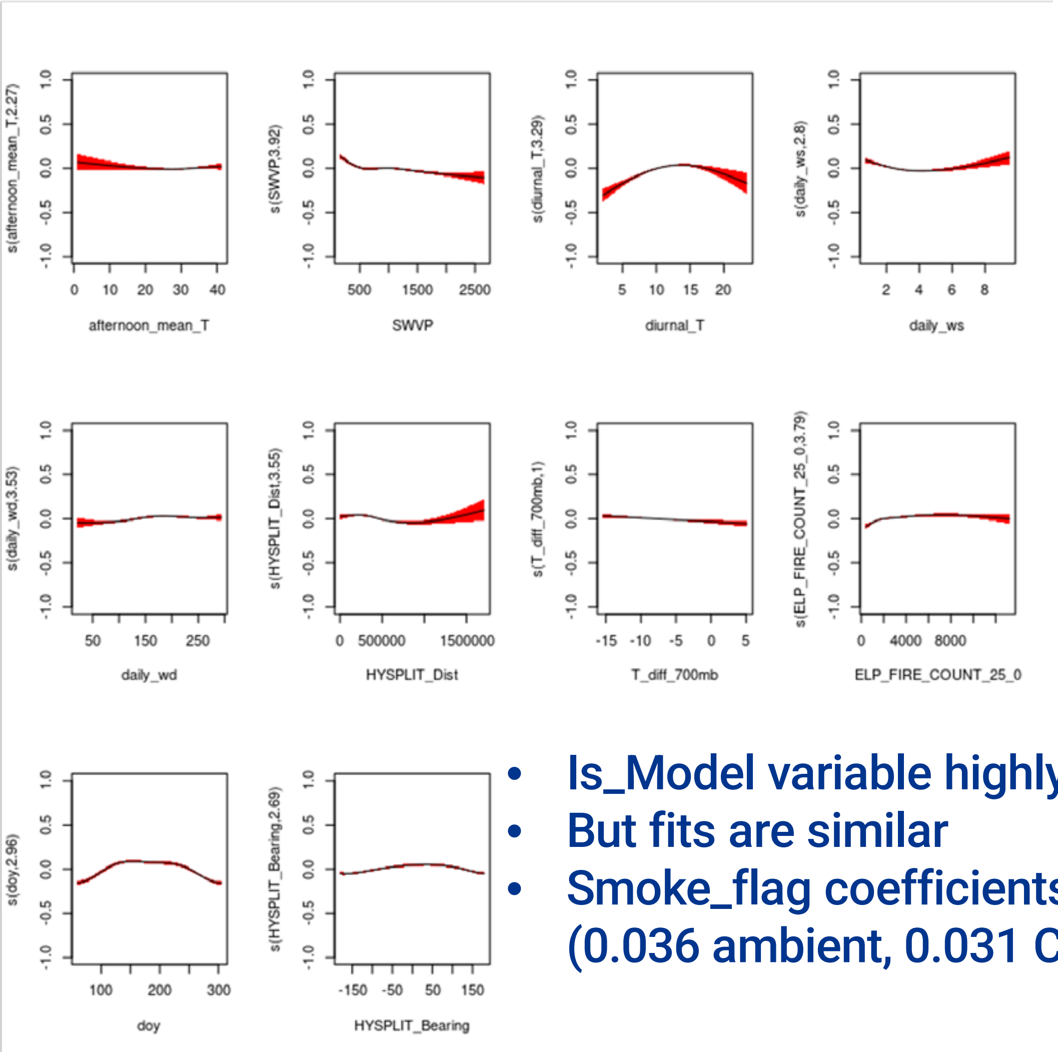
- Estimated smoke impacts are very similar in ambient data and CAMx simulations (within 0.4 ppbv)
- This, plus similarity of the smooth function fits and the smoke_flag coefficient, suggest CAMx does a reasonable job modeling the impact of smoke on maximum O_3 in El Paso, even while underestimating the absolute values

El Paso Background MDA8 O_3

(a) Ambient



(b) With CAMx



- Is_Model variable highly significant
- But fits are similar
- Smoke_flag coefficients similar (0.036 ambient, 0.031 CAMx)

El Paso Background MDA8 O_3: Total O_3 Predictions

	Ambient (ppbv) (Is_Model = 0)	CAMx (ppbv) (Is_Model = 1)	% Difference
Minimum	33.7	32.1	-5%
25th Percentile	42.3	42.0	-1%
Median	48.2	46.2	-4%
Mean	47.6	45.9	-4%
75th percentile	52.5	50.6	-4%
Max	61.4	58.1	-5%
Std. Dev.	6.3	5.9	

- CAMx underestimates background O_3 in El Paso, but percentage underestimate is relatively constant

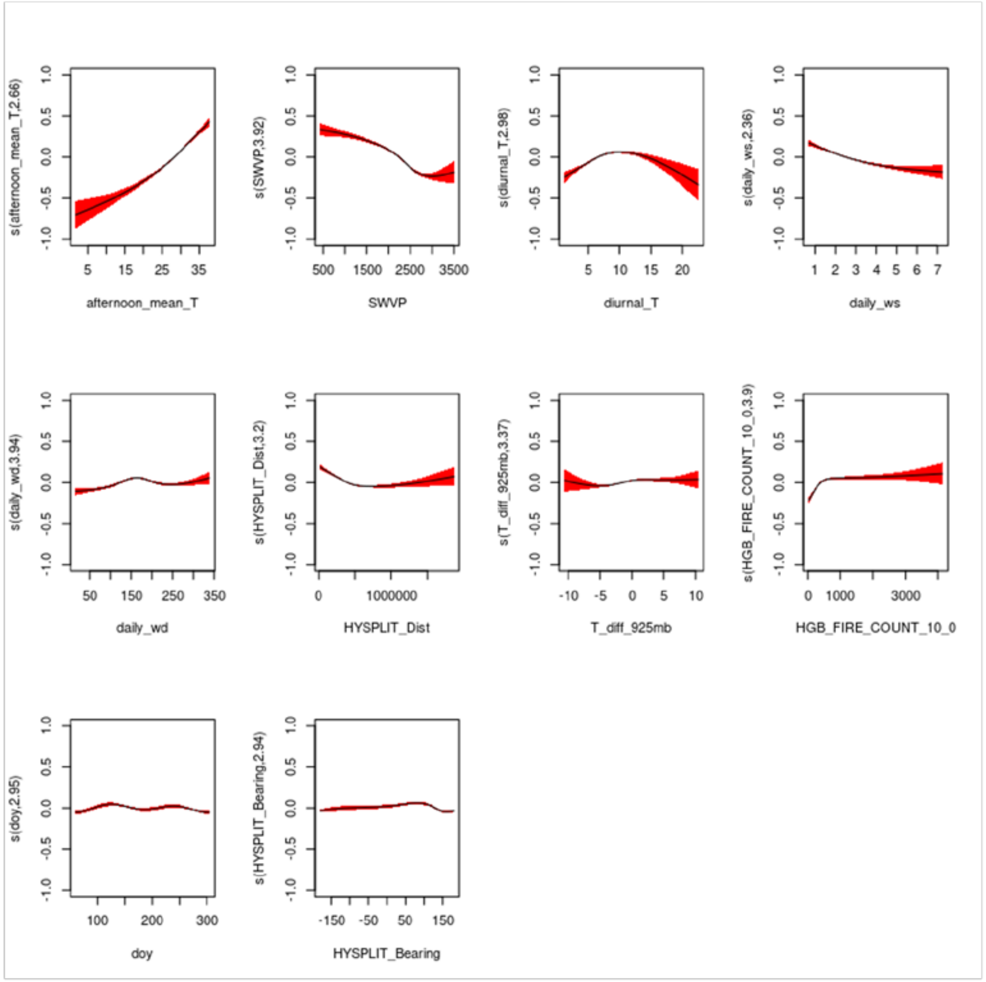
El Paso Background MDA8 O_3: Smoke O_3 Predictions

	Ambient (ppbv)	CAMx (ppbv)
Minimum	4.6	4.4
25th Percentile	6.3	6.0
Median	6.5	6.1
Mean	6.4	6.0
75th percentile	6.6	6.3
Max	7.6	7.2
Std. Dev.	0.8	0.8

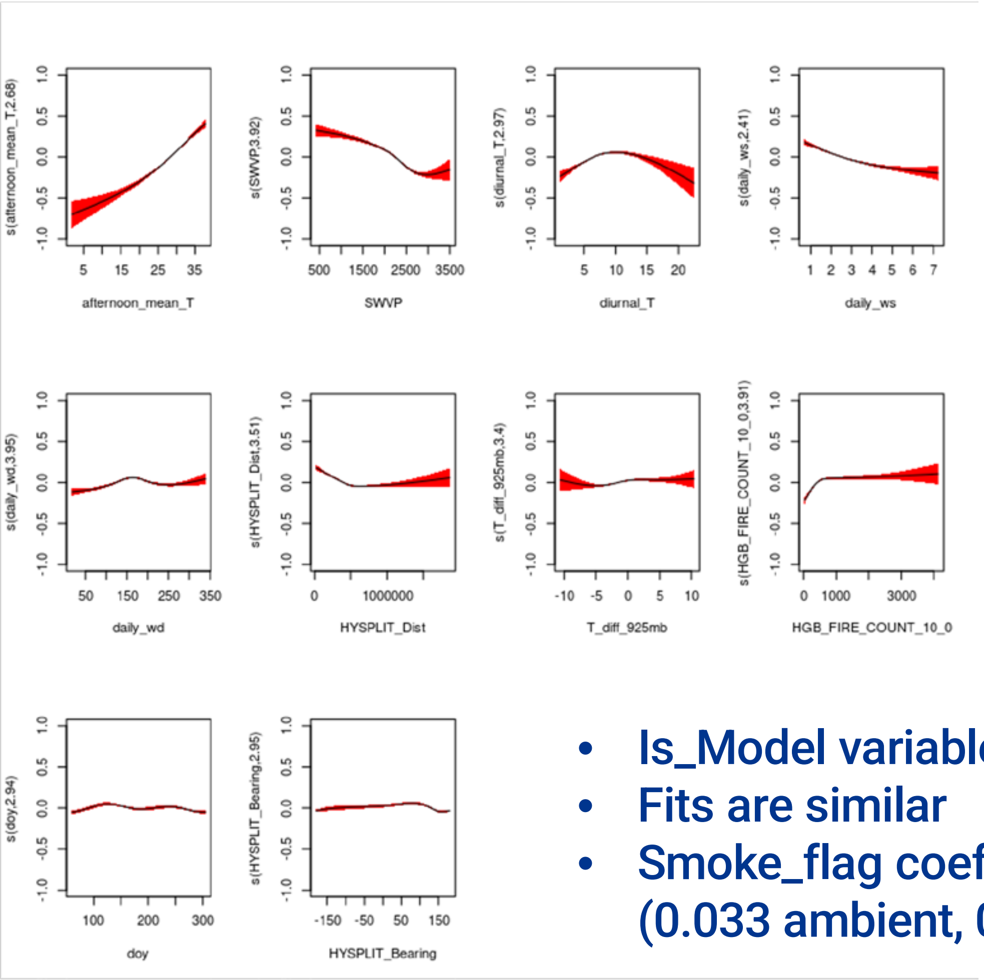
- As with maximum, estimated smoke impacts are very similar in ambient data and CAMx simulations (within 0.4 ppbv), suggesting CAMx does a reasonable job
- Both suggest a ~ 2 ppbv loss of O_3 when smoke enters El Paso

Houston Maximum MDA8 O_3

(a) Ambient



(b) With CAMx



- Is_Model variable **NOT** significant
- Fits are similar
- Smoke_flag coefficients similar (0.033 ambient, 0.034 CAMx)

Houston Maximum MDA8 O_3: Total O_3 Predictions

	Ambient (ppbv) (Is_Model = 0)	CAMx (ppbv) (Is_Model = 1)	% Difference
Minimum	27.7	28.2	2%
25th Percentile	42.7	43.7	2%
Median	50.2	51.2	2%
Mean	52.4	53.9	3%
75th percentile	61.3	62.5	2%
Max	82.9	84.1	1%
Std. Dev.	12.5	12.6	

- CAMx has small (2%) overestimates in Houston, constant through distribution

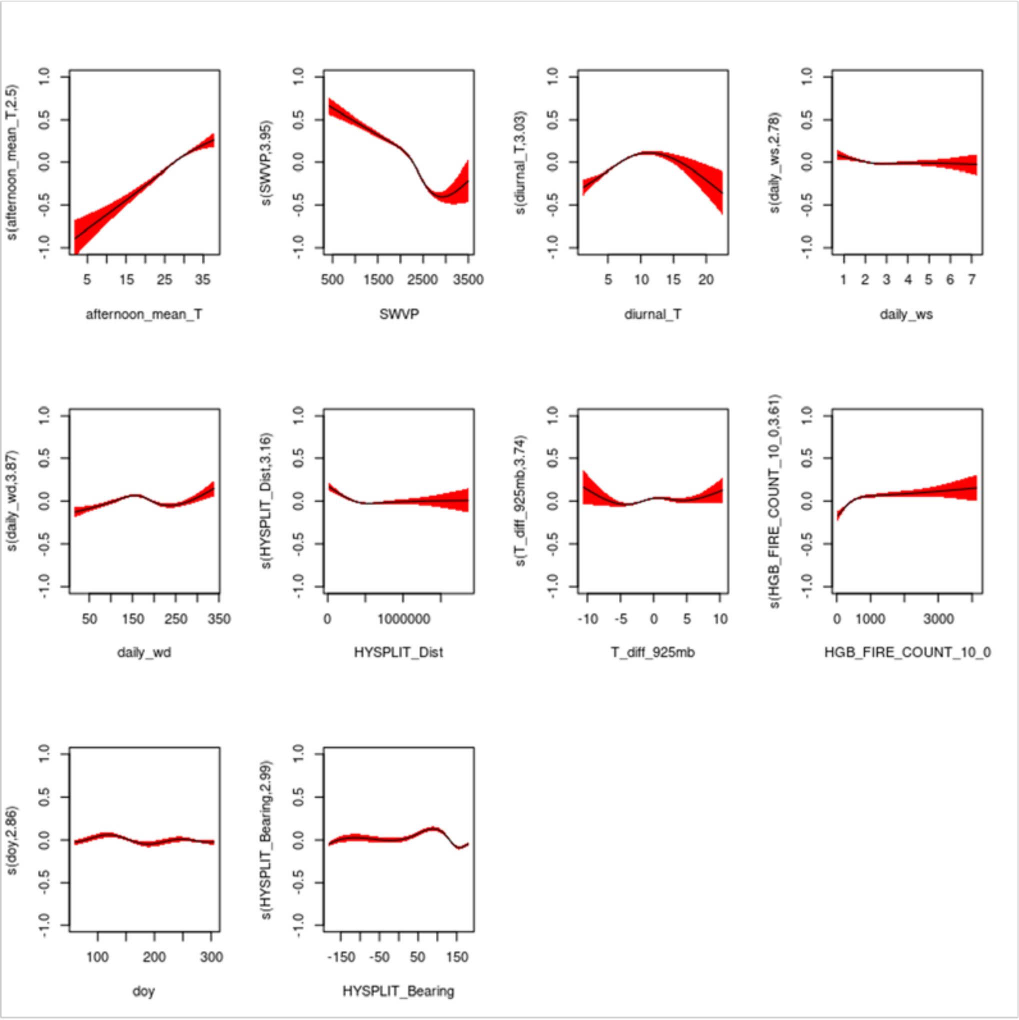
Houston Maximum MDA8 O_3: Smoke O_3 Predictions

	Ambient (ppbv)	CAMx (ppbv)
Minimum	9.4	11.0
25th Percentile	12.7	12.9
Median	15.3	15.6
Mean	15.6	15.8
75th percentile	18.3	18.1
Max	21.5	21.8
Std. Dev.	3.4	3.3

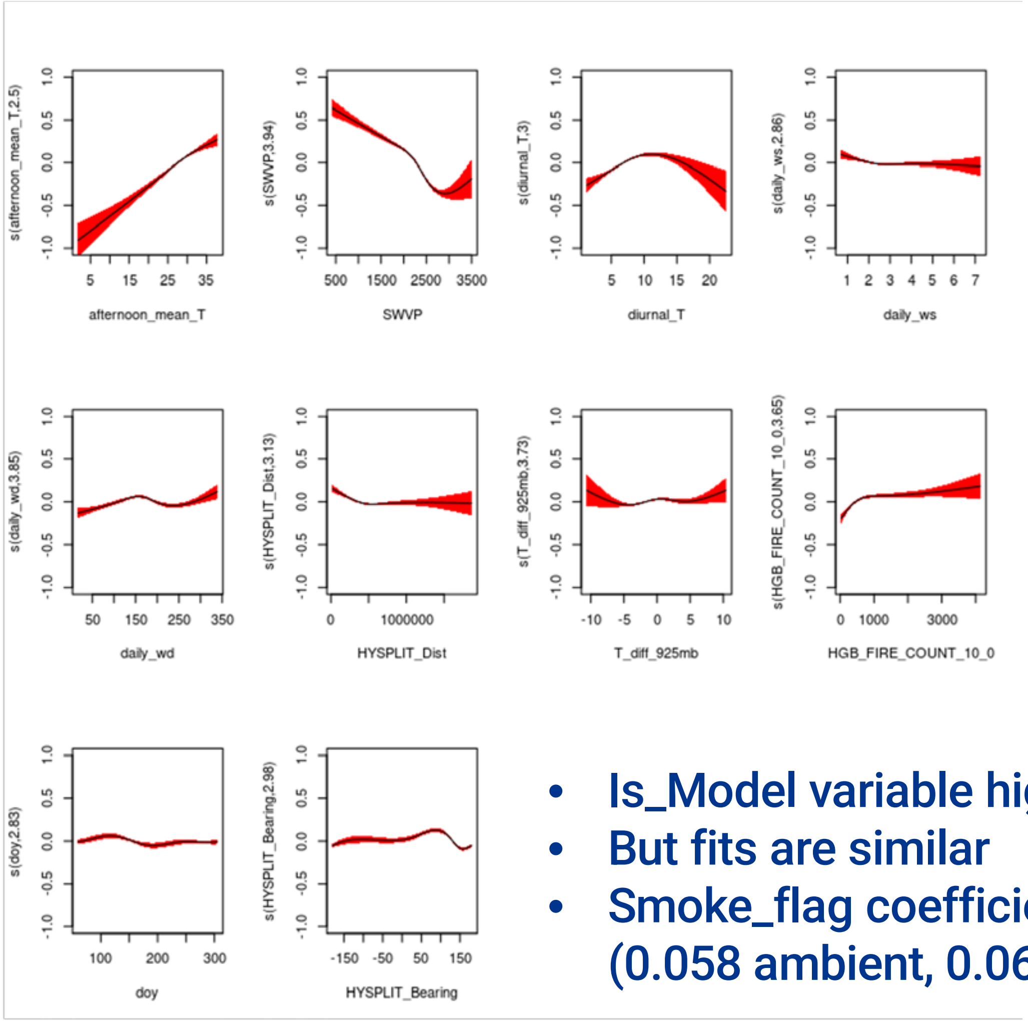
- Estimated smoke impacts are very similar in ambient data and CAMx simulations (within 0.3 ppbv except for minimum), suggesting CAMx does a reasonable job

Houston Background MDA8 O_3

(a) Ambient



(b) With CAMx



- Is_Model variable highly significant
- But fits are similar
- Smoke_flag coefficients similar (0.058 ambient, 0.063 CAMx)

Houston Background MDA8 O_3: Total O_3 Predictions

	Ambient (ppbv) (Is_Model = 0)	CAMx (ppbv) (Is_Model = 1)	% Difference
Minimum	16.4	20.2	23%
25th Percentile	23.9	28.9	21%
Median	28.9	35.5	23%
Mean	31.0	37.6	21%
75th percentile	37.2	45.4	22%
Max	57.6	67.0	16%
Std. Dev.	9.1	11.0	

- CAMx has large overestimates of background O_3 in Houston, causing the Is_Model variable to be significant

Houston Background MDA8 O_3: Smoke O_3 Predictions

	Ambient (ppbv)	CAMx (ppbv)
Minimum	5.6	8.4
25th Percentile	8.1	10.1
Median	9.2	11.1
Mean	9.7	11.6
75th percentile	10.9	13.0
Max	16.1	18.1
Std. Dev.	2.4	2.3

- CAMx predicts 2 ppbv more background O_3 impact of smoke in Houston than in ambient data
- CAMx suggests a net O_3 increase of 4 ppbv when the smoke enters the city, ambient data suggests 6 ppbv

Summary

- Only Houston Maximum MDA8 O_3 shows no significant difference between ambient and CAMx data when evaluated with the GAMs
- Only Houston Background MDA8 O_3 shows significant (> 1 ppbv) different between smoke impacts
- Houston Background MDA8 O_3 is also strongly (> 20%) overestimated in CAMx
- El Paso Maximum MDA8 O_3 is underestimated by CAMx, with a more severe underestimate at high O_3 levels (-10%).

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Objective 3: Directions for CAMx Modeling Improvements

Directions for CAMx Improvement

- Smoke impacts on O_3 were similar in ambient data and CAMx data except for Houston background O_3, which was overestimated (2 ppb) in CAMx.
  - Since this impact seems mainly due to transport from Mexico/Yucatan, this could be due to errors in initial fire emissions, the formation of O_3 in the Yucatan plume, or the chemistry over the Gulf during transport.
  - May also be related to overestimate of Houston background O_3 in CAMx

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Conclusions and Future Work

Conclusions

- On days when the HMS indicated smoke over Houston and El Paso:
  - The daily average $PM_{2.5}$ was elevated by 1.4-2.6 μg/m^3 on average
  - The background MDA8 O3 was elevated by 2.4-8 ppbv on average.
- The results depend strongly on which set of fire predictors is used.
  - For Houston, the change in O_3 impact as the smoke enters the city varies from -0.9 ppbv to +6.0 ppbv.
  - In El Paso, the change in mean O_3 impact as the smoke enters the city varies from -1.6 ppbv to -0.5 ppbv.
- For El Paso, our CAMx analysis suggested that there were statistically significant differences between CAMx and the ambient data, but further analysis showed that the predicted impacts of fires in both cases were very similar.
- For Houston, the differences between CAMx and the ambient data fits were not statistically significant for maximum O_3, but the CAMx data strongly overestimates the background O_3 for Houston on both smoky and non-smoky days and overestimates the smoke impact on background O_3 by 2 ppbv.

Limitations of this Study

- Difficult to separate impacts of meteorology from smoke
  - Leads to smoke impact predictions depending strongly on what smoke predictors are included
- Looked at all levels of HMS smoke equally, did not separate heavy, medium, and light
- Only had 2019 CAMx data available
  - Longer runs using EQUATES dataset could help in evaluation with statistical models
- Did not include ambient measurements of precursor species (NO_x, VOCs), fire-related species (CO, HCN), or $PM_{2.5}$ speciation (OC, EC)
  - Reliance on HMS to identify smoke days may introduce error due to lack of vertical information
  - But these measurements are limited to a small number of sites and days

Recommendations for Future Work

- Future work should focus on finding ways to better determine the best set of smoke predictors for use in statistical studies such as this, with a focus on high tail events where smoke could lead to an exceedance of air quality standards using methods from Brown-Steiner et al. (2021).
- While the predictions of smoke impact on O_3 from CAMx appear to be reasonable based on this study, our results suggest that further work is needed to (a) address the overestimate of Houston background O_3 on both smoky and non-smoky days and (b) the underpredictions of maximum O_3 in El Paso.

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