Developing Agricultural Burning Emissions Inventories to Support the Quantification of Fire-Related Ozone Impacts for an Exceptional Event Demonstration

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Presentation Outline

- Background
  - Exceptional Events
  - Flint Hills Fires
- Methods
  - BlueSky Gateway
  - Fire Emissions Processing
- Results
- Conclusions

Smoke and Air Pollution

- Smoke from fires contains $PM_{2.5}$, NO_x, VOCs, and other pollutants

- Smoke from fires is associated with negative health effects

- Fire events can trigger violations of the ozone and PM NAAQS

Fire in Wabaunsee County, Kansas

Exceptional Events

- Unusual or naturally occurring events that affect air quality but are not reasonably controllable or preventable

- EPA has considered wildland and prescribed fires to be exceptional events under some circumstances

- States can exclude measurements from regulatory determinations by demonstrating that the data were influenced by an exceptional event (EE)

- Technical evidence of such influences must be submitted to EPA as a **demonstration package**

Exceptional Event Demonstrations

- Must include analyses showing that *no NAAQS exceedance would have occurred* **"but for"** *the exceptional event*

- "But for" demonstrations include a quantitative assessment of ozone levels with and without fire

- Because ozone is a secondary pollutant, meeting the "but for" requirement is particularly challenging

- **Numerical modeling** was used to support an EE demonstration for the Kansas Department of Health and Environment (KDHE)
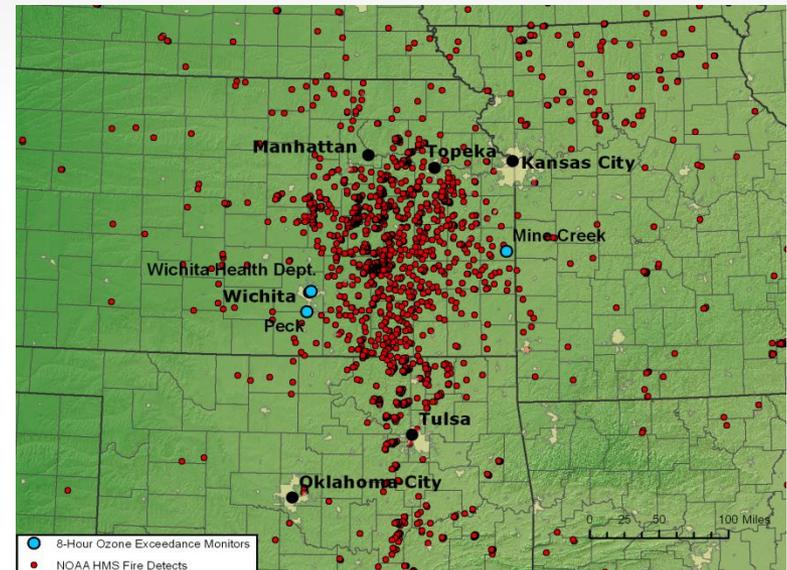
Flint Hills Prescribed Burning (1)

- The Flint Hills region in eastern Kansas covers 10,000 mi^2 and is the largest tallgrass prairie ecosystem in North America

- Over 1 million acres of rangeland are burned each spring to improve cattle grazing and ecosystem health

- Populated metropolitan areas are adjacent to the Flint Hills region

Flint Hills Prescribed Burning (2)

- In April 2011, extensive burning occurred in the Flint Hills region

- Air quality monitors in nearby cities recorded several violations of EPA's 8-hr NAAQS for ozone of **75 ppb**

- STI performed emissions and modeling analyses to support KDHE in developing an EE demonstration package for these events
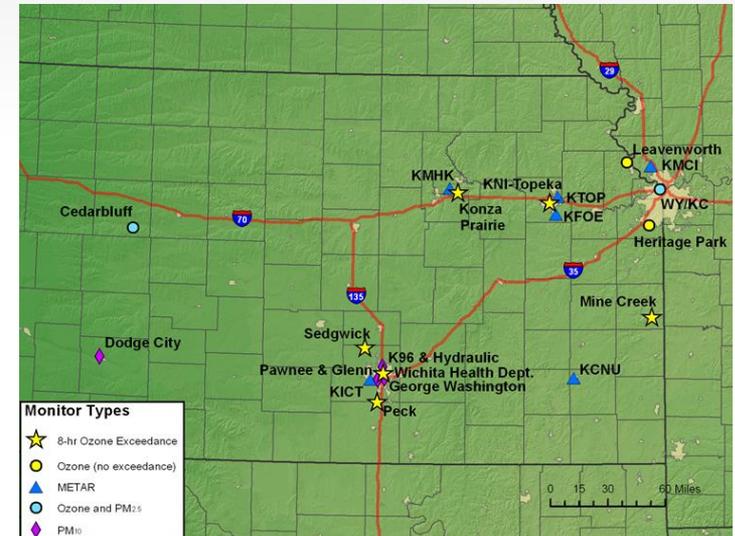

Satellite fire detections on April 6, 2011

Prescribed burn in the Kansas Flint Hills

Ozone NAAQS Exceedances

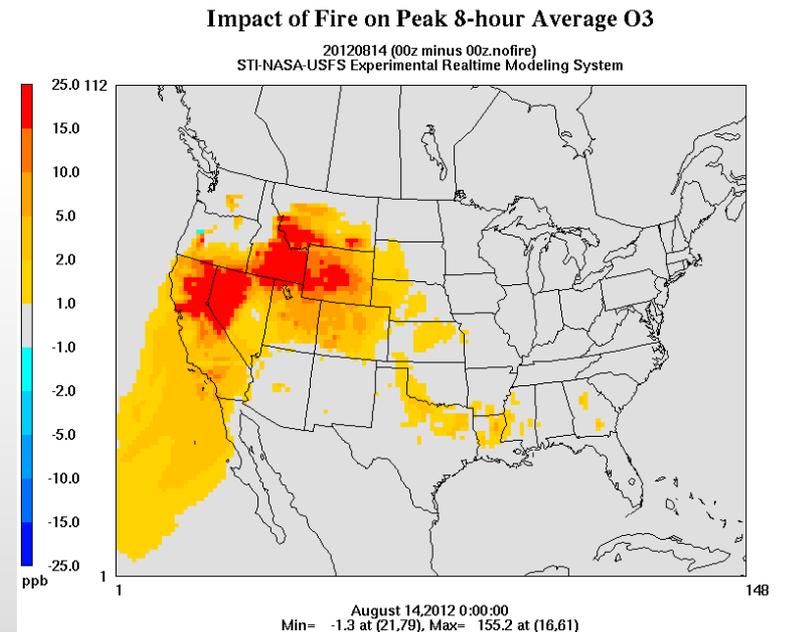| Monitor	Date in 2011	8-hr O_3 Concentration (ppb)
Mine Creek	April 6	76
Peck	April 6	82
Wichita Health Dept.	April 6	79
KNI-Topeka	April 12	84
Konza Prairie	April 12	78
Konza Prairie	April 13	79
Peck	April 29	77
Sedgwick	April 29	82

- Peak ozone values are historically unusual for this region in April (above 95th percentile)
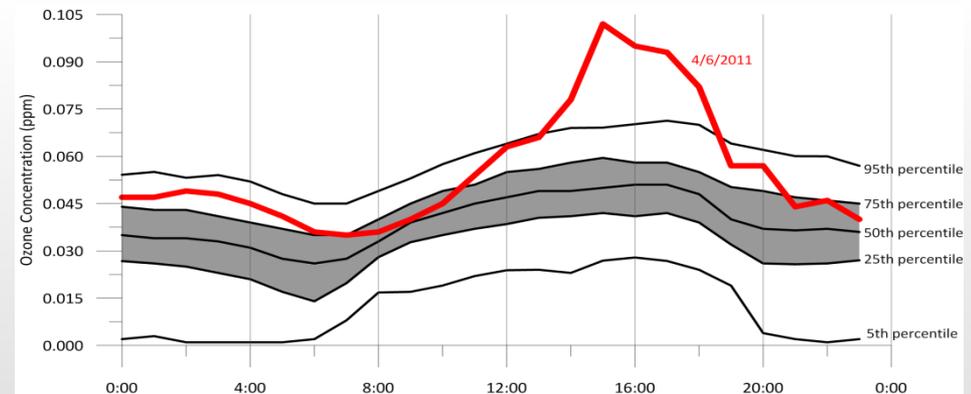
Modeling Methods

- BlueSky Gateway Smoke Modeling System
  - Developed by STI and the USDA Forest Service to forecast fire impacts on air quality at a national scale
  - Features the SmartFire system for reconciling fire information from multiple data sources (e.g., satellites and ground-based reports)
  - Daily runs of the MM5 meteorological model (now WRF) and the CMAQ photochemical grid model at a 36-km grid resolution
  - Retrospective simulations run for April 2011 using detailed information on the Flint Hills fires

Right: Sample BlueSky Gateway product showing fire impacts on ozone for August 14, 2012.

Impact of Fire on Peak 8-hour Average O3
20120814 (00z minus 00z.nofire)
STI-NASA-USFS Experimental Realtime Modeling System

August 14,2012 0:00:00
Min= -1.3 at (21,79), Max= 155.2 at (16,61)

Emissions Estimation (1)

$$\text{Emissions } = A \text{ x } AFL \text{ x } \beta \text{ x } Ef$$

Where:

A Area burned (e.g., acres, km^2)

AFL Available fuel load (biomass per unit area)

β Burning efficiency (fraction of biomass consumed)
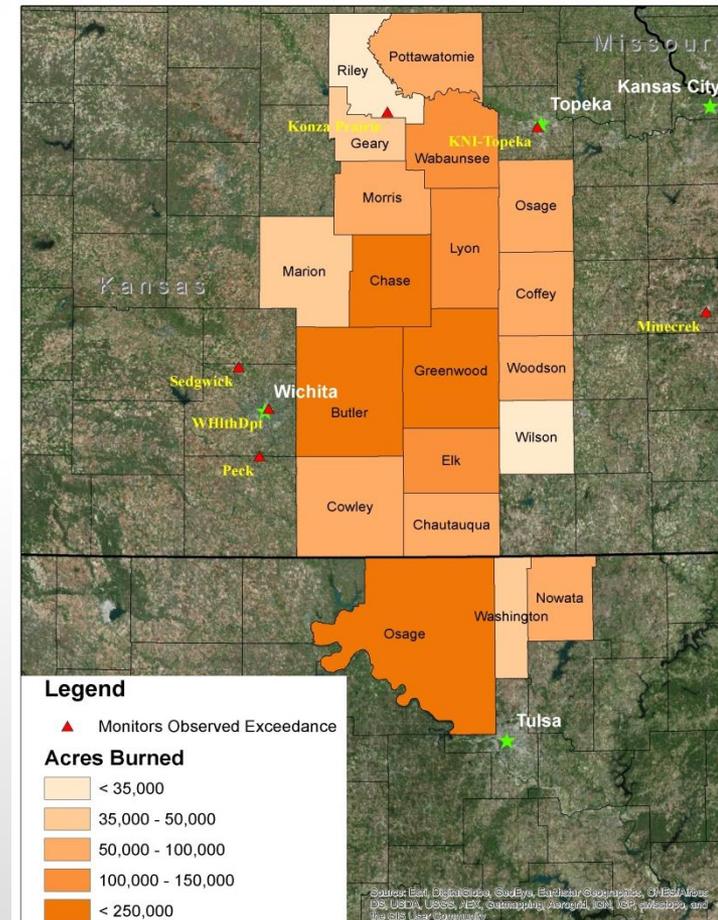
Ef Emission factors (mass of pollutant per quantity of biomass consumed)

Emissions Estimation (2)

$$E = A \times AFL \times \beta \times Ef$$

Fire Activity (area burned):

- Daily, county-level burn acreages developed by KDHE and Kansas State University using burn scar analyses and burn reports from county agriculture extension offices

- Burn acreage allocated to model grid cells based on typical burn practices

Legend

▲ Monitors Observed Exceedance

Acres Burned

- < 35,000
- 35,000 - 50,000
- 50,000 - 100,000
- 100,000 - 150,000
- < 250,000

Emissions Estimation (3)

$$E = A \times AFL \times \beta \times Ef$$

AFL — County-specific fuel loading data provided by KDHE

β — Assumed burn efficiency of 100%

Ef — Emission rates from the Fire Emission Production Simulator (FEPS)

Also, a "top-hat" diurnal profile was used to allocate daily emissions evenly across typical burn hours of 10:00 a.m. to 6:00 p.m.

Emissions Estimation (4)

- For fires outside the Flint Hills, emissions estimates were developed using the standard BlueSky Framework pathway

- Non-fire anthropogenic emissions were used from EPA's 2008 National Emissions Inventory (NEI)

- Fire and non-fire emissions processed through the SMOKE emissions model and merged to create CMAQ-ready inputs
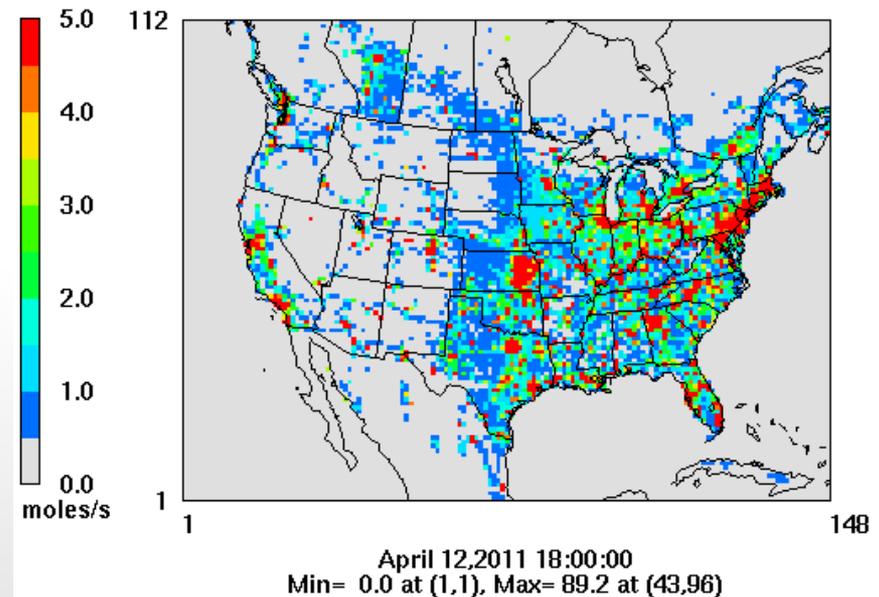
Merged, CMAQ-ready NO emissions for April 12, 2011.
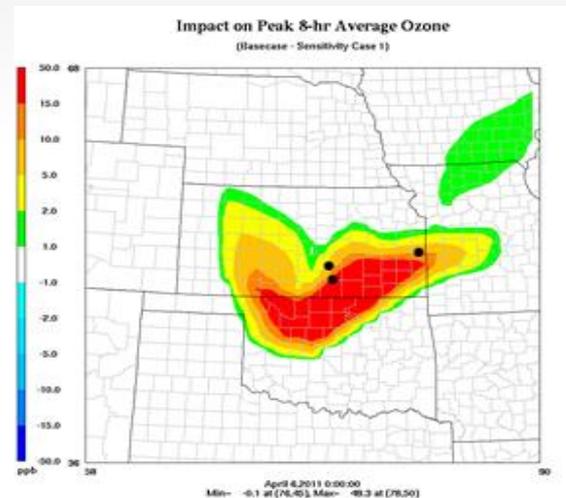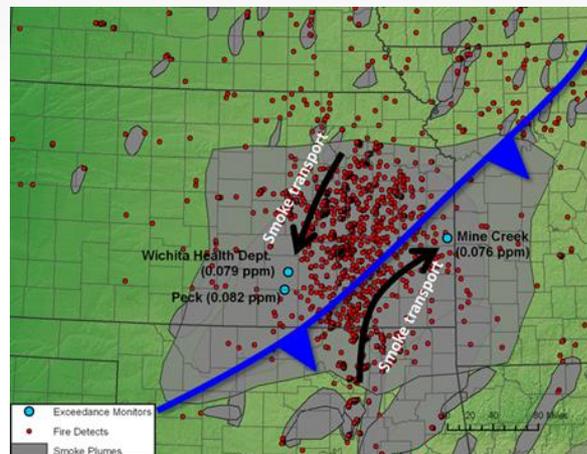
Model Performance Analysis

- Gateway captured general ozone trends for April 2011.

- Mean bias: -4.5 ppb to 1.8 ppb
- Normalized mean error: 9% to 18%
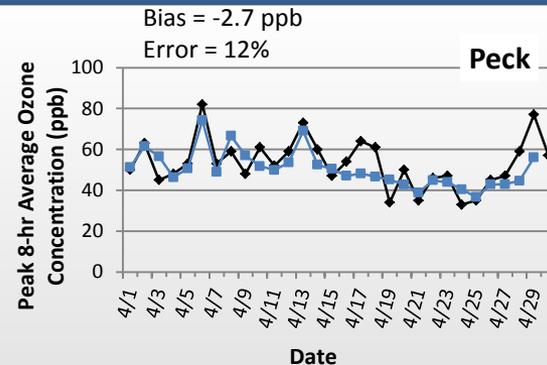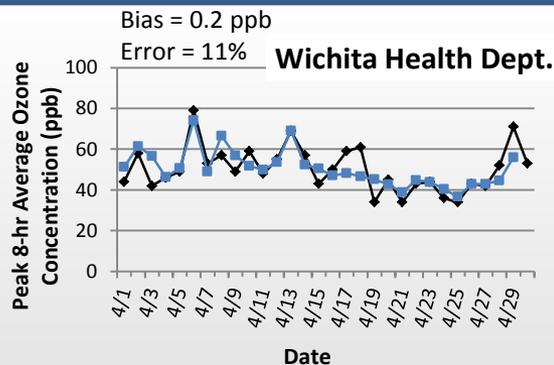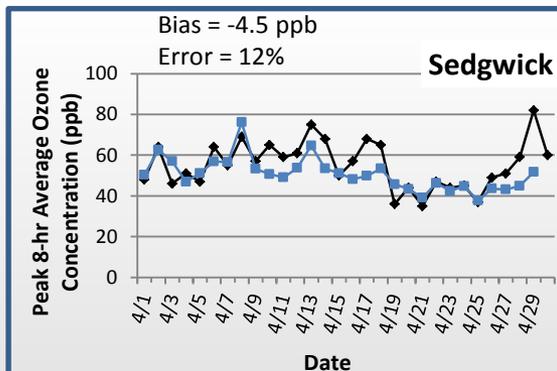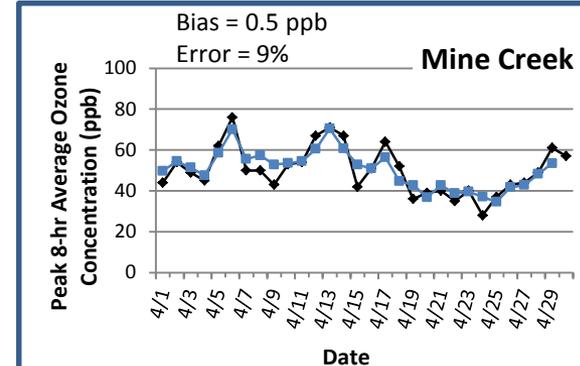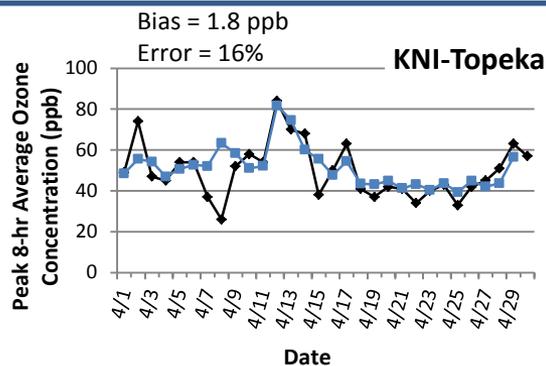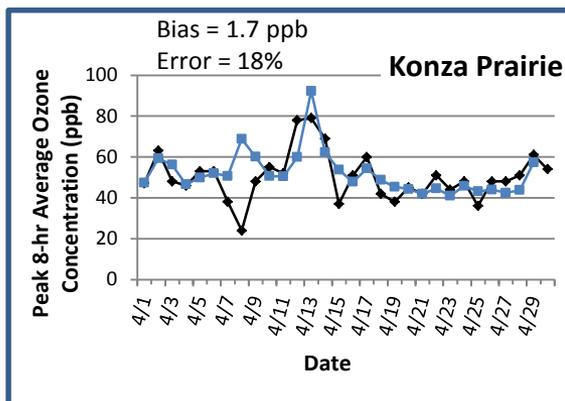
April 6, 2011

- 248,000 acres burned.

- Complex flow pattern due to midday frontal passage.

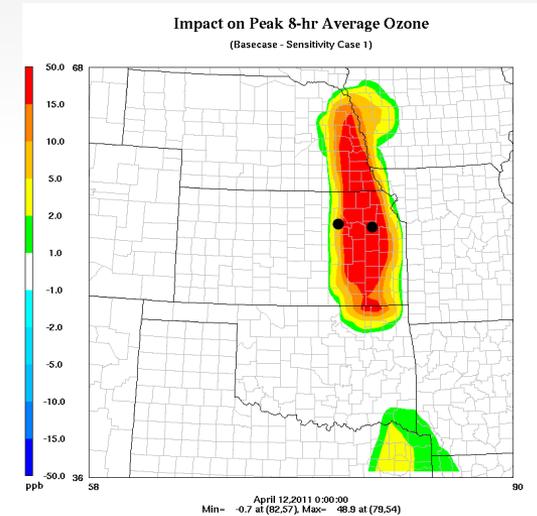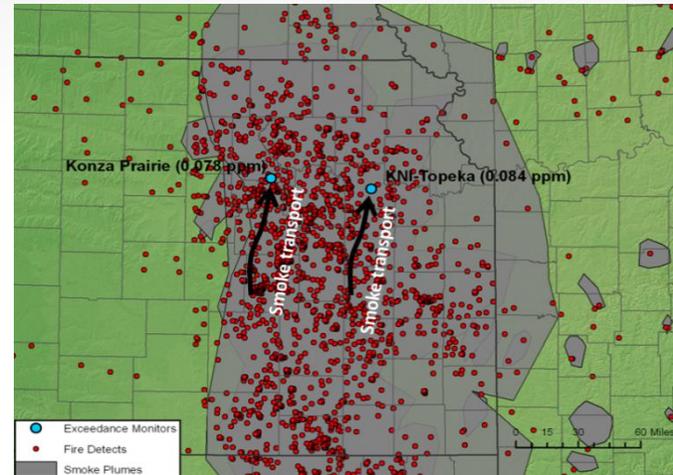- Ozone would not have exceeded 75 ppb "but for" the smoke.

Monitor	Observed	CMAQ All Fires	CMAQ No Flint Hills Fires	Impact of Flint Hills Fires
Mine Creek	76	70	60	**10**
Wichita	79	74	54	**20**
Peck	82	74	54	**20**

Modeled impact of Flint Hills fires on 8-hour average ozone (ppb)

April 12, 2011

- 298,000 acres burned.

- Smoke transport by southerly winds.

- Ozone would not have exceeded 75 ppb "but for" the smoke.

Monitor	Observed	CMAQ All Fires	CMAQ No Flint Hills Fires	Impact of Flint Hills Fires
KNI-Topeka	84	82	54	**28**
Konza Prairie	78	60	53	**7**

Modeled impact of Flint Hills fires on 8-hour average ozone (ppb)

April 13, 2011

- 291,000 acres burned.

- Southeast winds transported smoke to Konza Prairie. Smoke carryover from prior days also important.

- Ozone would not have exceeded 75 ppb "but for" the smoke.
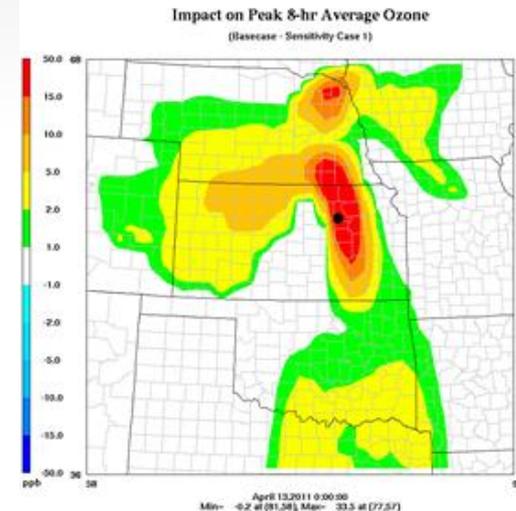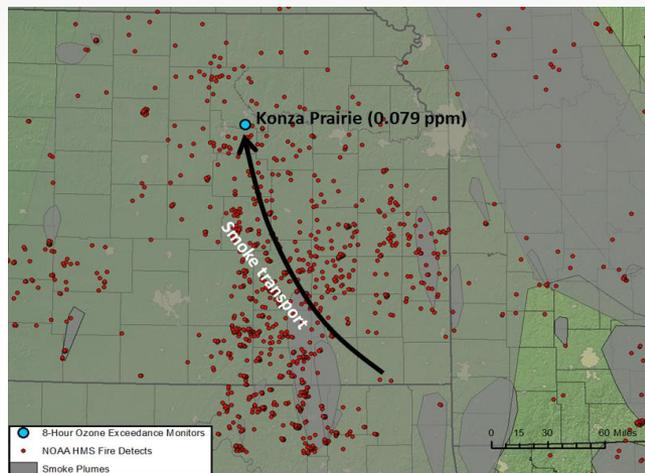
Monitor	Observed	CMAQ All Fires	CMAQ No Flint Hills Fires	Impact of Flint Hills Fires
Konza Prairie	79	92	62	**30**

Modeled impact of Flint Hills fires on 8-hour average ozone (ppb)

April 29, 2011

- Only 19,000 acres burned in the Flint Hills.

- Numerous large fires in Texas and Mexico, with region-wide ozone enhancement.

- Modeling showed no ozone impact due to Flint Hills fires. Ozone enhancement at the Kansas monitors was due to long-range smoke transport.
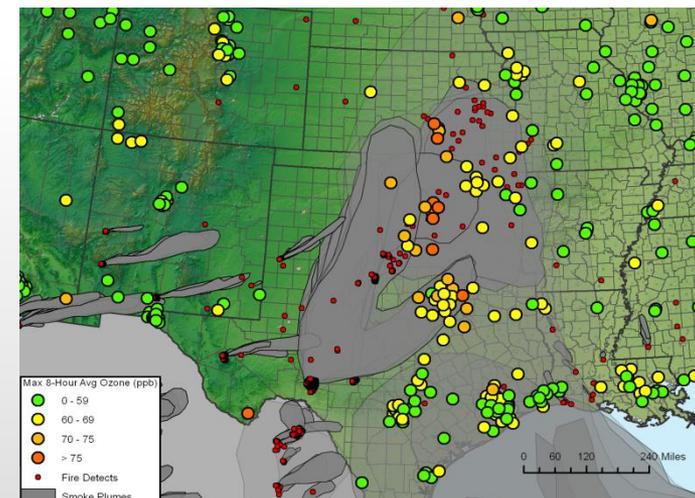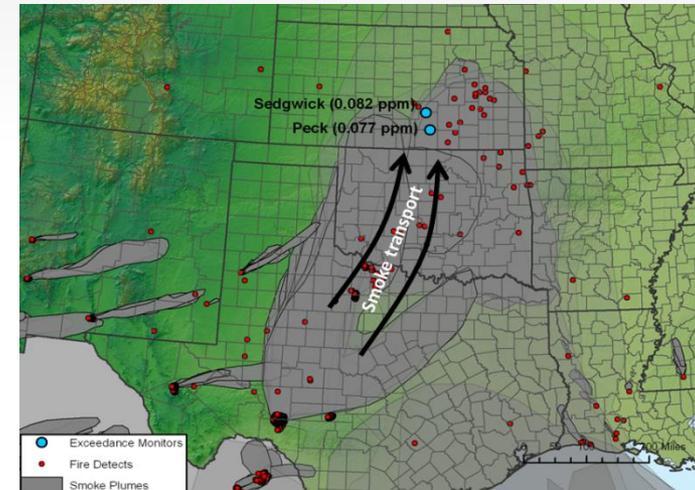
Conclusions (1)

- Emissions and modeling analyses were successfully applied to support an exceptional event analysis. EPA concurred that the analysis satisfied the exceptional event demonstration requirements

- For 3 of 4 NAAQS exceedance days in Kansas, analysis helped demonstrate that NAAQS ozone exceedances would not have occurred "but for" the smoke from Flint Hills fires

- Modeled fire impacts on 8-hour ozone levels ranged from 5 ppb to 30 ppb at Kansas monitors during April of 2011

Conclusions (2)

- KDHE has developed a Smoke Management Plan to mitigate smoke impacts on urban areas

- STI has worked with KDHE to develop a web-based burn decision support system

- The system provides managers with daily smoke forecasts and guidance on when and where to burn

- The system is currently operational for the 2015 Flint Hills fire season
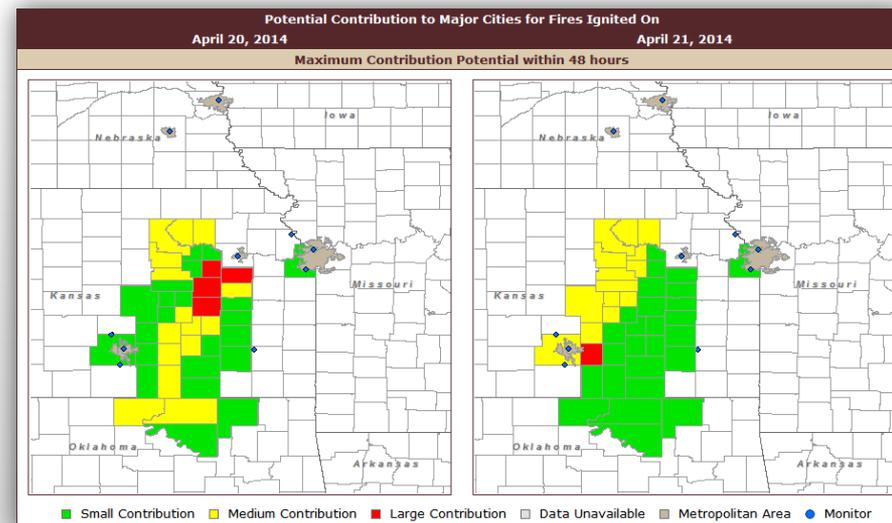
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