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$PM_{2.5}$ & Secondary $PM_{2.5}$ Analysis for PSD Permitting: A Case Study in Missouri

March, 2015

Sarah Teefey

Presentation Overview

- $PM_{2.5}$ Background
- EPA Guidance for $PM_{2.5}$ Permit Modeling
- Case Study
  - Part 1: Identifying a Representative $PM_{2.5}$ Monitor
  - Part 2: Quantifying Secondary $PM_{2.5}$ as part of Demonstrating Compliance with NAAQS & PSD Increments

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$PM_{2.5}$ Background

- $PM_{2.5}$
  - Particulate matter less than 2.5 micrometers in diameter.
- Primary $PM_{2.5}$
  - $PM_{2.5}$ emitted directly from a source.
- Secondary $PM_{2.5}$
  - $PM_{2.5}$ formed from the chemical reaction of precursor pollutants emitted from a source downwind of the original pollution source.
    - Precursors include NO_x and SO_2

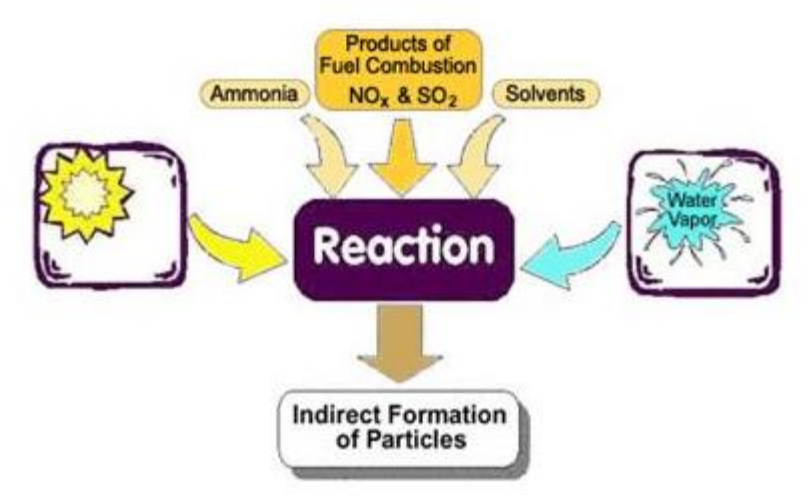

Chart Courtesy of the Bay Area Air Quality Management District

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$PM_{2.5}$ Background

- First NAAQS for $PM_{2.5}$ was established in 1997.
- EPA allowed PM_{10} to serve as surrogate for $PM_{2.5}$ in PSD BACT and air quality analysis until May 2011.
  - Since May 2011, $PM_{2.5}$ must be considered on its own.
  - Challenge since has been how to account for the secondary piece.

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Challenges Associated with Accounting for Secondary $PM_{2.5}$

- Complexities of the chemistry and atmospheric reactions at play important in any analysis of $PM_{2.5}$.
- EPA approved model for evaluation of near field impacts, AERMOD, not capable of directly evaluating chemistries for secondary $PM_{2.5}$.
- Correlation of primary and secondary impacts – magnitude of secondary impacts varies with time/distance.
- Impacts vary by season.
- The regulated community, and regulators, need guidance…..

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EPA & $PM_{2.5}$

- New EPA Guidance: "Guidance for $PM_{2.5}$ Permit Modeling" from May 2014
  - Emphasis on secondary $PM_{2.5}$
  - Cannot use AERMOD to simulate secondary $PM_{2.5}$
    - "The accounting for precursor emissions impact on secondary $PM_{2.5}$ formation may be: a) **qualitative** in nature; b) based on a **hybrid of qualitative and quantitative** assessments utilizing existing technical work; or c) a **full quantitative** photochemical grid modeling exercise."

EPA May 2014 Guidance Summary

Assessment Case	Description of Assessment Case	Primary Impacts Approach	Secondary Impacts Approach
Case 1: No Air Quality Analysis	Direct PM2.5 emissions < 10 tpy SER NOx and SO2 emissions < 40 tpy SER	N/A	N/A
Case 2: Primary Air Quality Impacts Only	Direct PM2.5 emissions ≥ 10 tpy SER NOx and SO2 emissions < 40 tpy SER	Appendix W preferred or approved alternative dispersion model	N/A
Case 3: Primary and Secondary Air Quality Impacts	Direct PM2.5 emissions ≥ 10 tpy SER NOx and/or SO2 emissions ≥ 40 tpy SER	Appendix W preferred or approved alternative dispersion model	• Qualitative • Hybrid qualitative / quantitative • Full quantitative photochemical grid modeling
Case 4: Secondary Air Quality Impacts Only	Direct PM2.5 emissions < 10 tpy SER NOx and/or SO2 emissions ≥ 40 tpy SER	N/A	• Qualitative • Hybrid qualitative / quantitative • Full quantitative photochemical grid modeling

Source: U.S. EPA, Guidance for PM2.5 Permit Modeling, May 2014, EPA-454/B-14-001

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Secondary $PM_{2.5}$ Assessment Methods (1 of 3)

- Completely **qualitative** needs much characterization
  - Develop "appropriate conceptual description of $PM_{2.5}$"
- Important considerations:
  - Characterization of current 24-hour and annual concentrations
  - Seasonal variations in typical $PM_{2.5}$ concentrations
  - Speciated composition of the current $PM_{2.5}$ concentrations and any long term trends occurring
  - What are typical background concentrations of precursors and how will project affect concentrations?
  - Characterize meteorological conditions representative of region and associated with periods of higher and lower $PM_{2.5}$ concentrations
  - Analysis of existing photochemical grid modeling for regional haze, ozone, and $PM_{2.5}$

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Secondary $PM_{2.5}$ Assessment Methods (2 of 3)

- Hybrid qualitative/quantitative approach
  - Some quantification of secondary $PM_{2.5}$ may be need to show source will not contribute to violation of NAAQS.
  - Add analysis of local/region specific "offset ratios" for precursor emissions (i.e. how readily the precursors form the fine particles in the modeled domain)
  - This approach may include a modeled "overlay" of direct $PM_{2.5}$ and a simplified approach for assessing the secondary formation
- EPA recommends consultation with Regional Office – applicants should work diligently with the permitting authority through the modeling protocol process

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Secondary $PM_{2.5}$ Assessment Methods (3 of 3)

- Quantitative approach
  - Photochemical Model (e.g., CAMx or CMAQ)
  - Only expected to be needed in “rare” cases
  - Very expensive and time consuming
  - Requires EPA Region and EPA Headquarters approval
  - Chemistry Plume Models? (e.g., SCICHEM, updated CALPUFF)

Since May 2014 Guidance, What are States Doing?

- Some States have already been requiring, and will continue to require, hybrid approach type assessments for secondary $PM_{2.5}$.
- Some States looking for guidance on what can justify qualitative versus hybrid versus quantitative.
- A common theme: case by case assessment.
  - State requirements regarding secondary $PM_{2.5}$ will be a constantly changing and evolving theme over the coming years.
  - The analysis your facility may have been allowed to do in one State, may not be acceptable (or desired) in another State.

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May 2014 Guidance Summary - Case Study Approach Determination

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Project Overview

- PSD permit required
  - $PM_{2.5}$, NO_x and SO_2 greater than SER
- Regulations have vacated $PM_{2.5}$ SMC (Significant Monitoring Concentration) so any increase over SER warrants review of existing concentrations
  - Conduct site specific monitoring
  - Find a representative $PM_{2.5}$ data from existing monitor
    - Represents concentrations surrounding proposed facility
    - Can be used to derive a "clean" background concentration

$$PSD = Modeled\ PM_{2.5} + Secondary\ PM_{2.5} + Background$$

    - Data from the monitor can also be used in qualitative/quantitative analysis

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A Case Study - Part 1
Identifying a Representative $PM_{2.5}$ Monitor

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Case Study: The Proposal

- Guidance allows use of existing monitor if <u>representative</u>.
- Proposed using $PM_{2.5}$ data collected at an existing $PM_{2.5}$ ambient air monitor in El Dorado Springs, Missouri.

http://www.epa.gov/airdata/ad_maps.html

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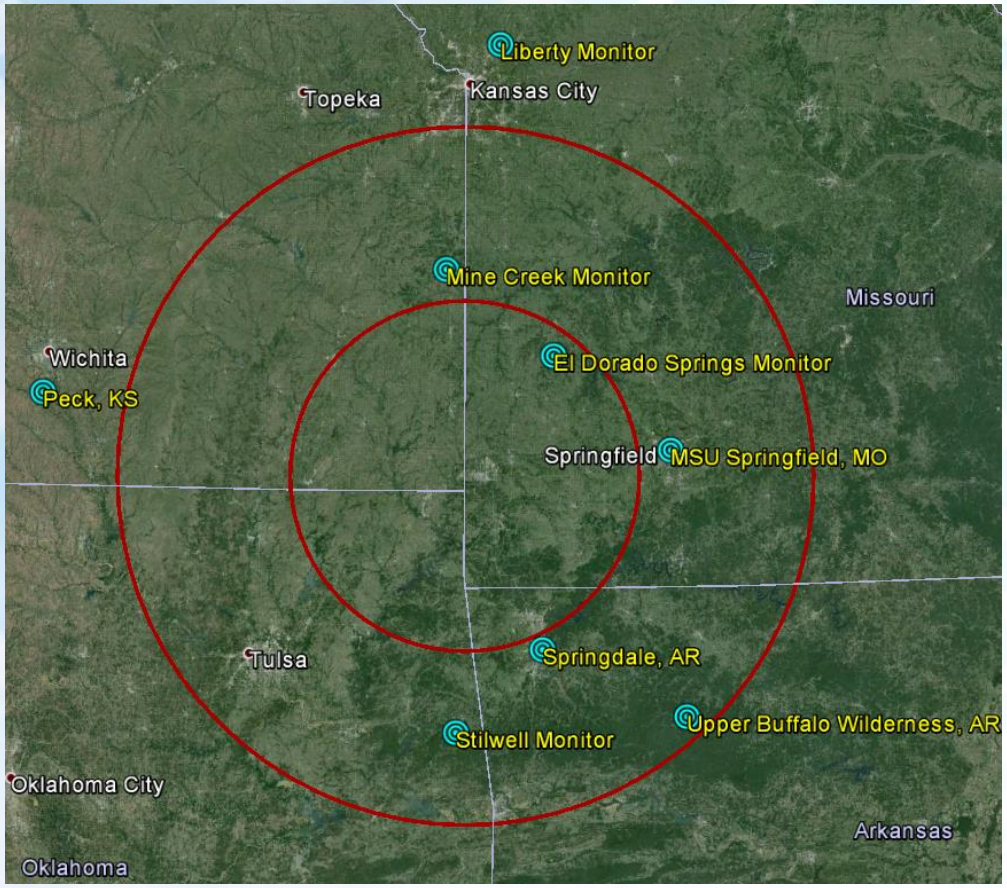
Case Study: Monitor Options

- Located all $PM_{2.5}$ monitors near facility.
- Narrowed options based on:
  - Data currentness
  - Data quality
  - Speciation of $PM_{2.5}$
  - Meteorological conditions in region



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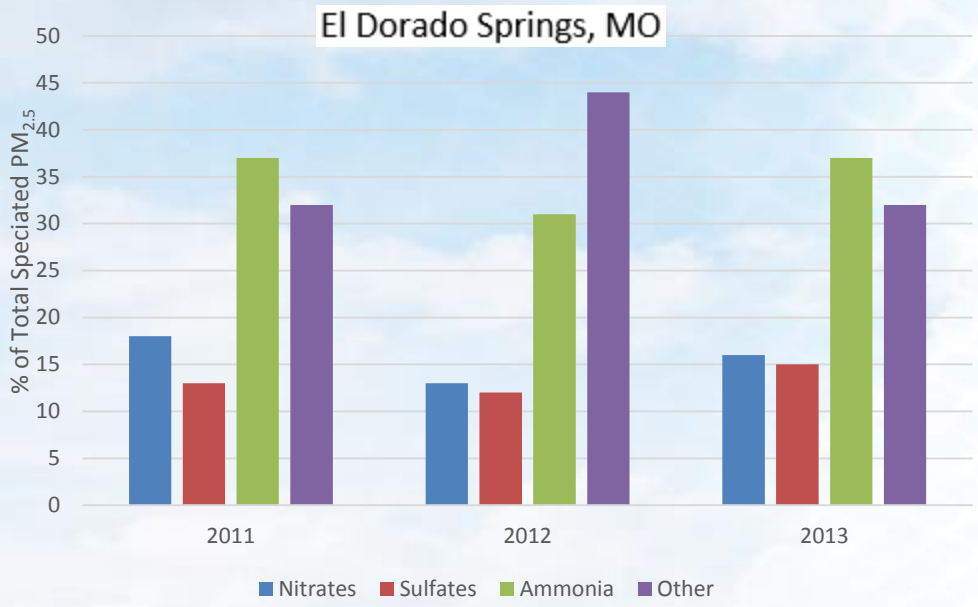
Case Study: Monitor Options

- Why are speciated monitors preferred?
  - Characterize chemical composition of the $PM_{2.5}$
  - Can evaluate PM in the form of nitrates, sulfates and ammonia



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Case Study: Monitor Options

Table 1. List of parameters measured at El Dorado Springs, Liberty, and Stilwell monitor sites

El Dorado Springs, MO	Liberty, MO	Stilwell, OK
AQS ID: 29-039-0001	AQS ID: 29-047-0005	AQS ID: 40-001-9009
Speciated $PM_{2.5}$ Concentration	Speciated $PM_{2.5}$ Concentration	Speciated $PM_{2.5}$ Concentration
Ozone Concentration	Ambient Temperature	Ozone Concentration
Barometric Pressure	Barometric Pressure	Outdoor Temperature
Outdoor Temperature	Wind Speed	24 Hour Rain Total
Wind Speed	Wind Direction	Wind Speed
Wind Direction	Relative Humidity	Wind Direction
Relative Humidity		Relative Humidity
		PM_{10} Concentration
		NO_x Concentration
		SO_2 Concentration

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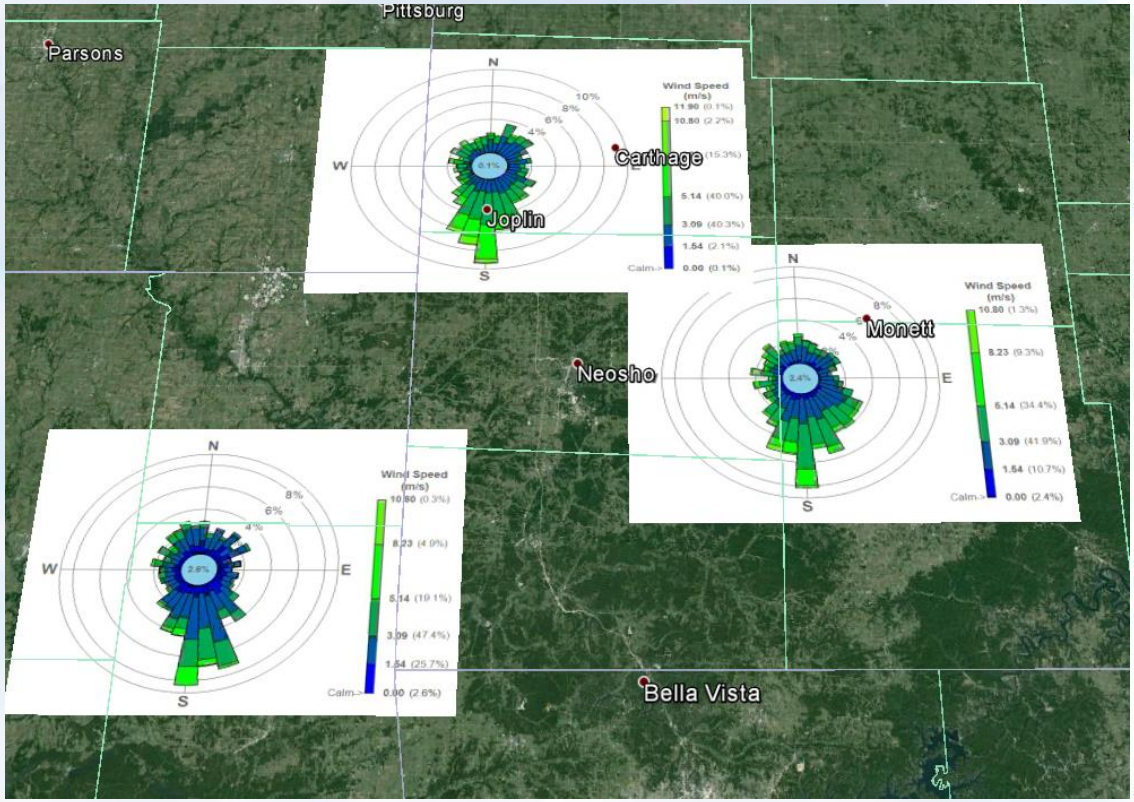
Case Study: Monitor Selection

- Which monitor is representative of the concentration in area of proposed facility?
  - Things to Consider:
    - Wind direction & air parcel trajectories
    - Climatology
    - Demographics of region
    - Surrounding sources of precursor pollutants

Case Study: Wind Analysis

- Determine average wind speed and direction near proposed facility location
  - 5 year analysis for 3 nearby airports



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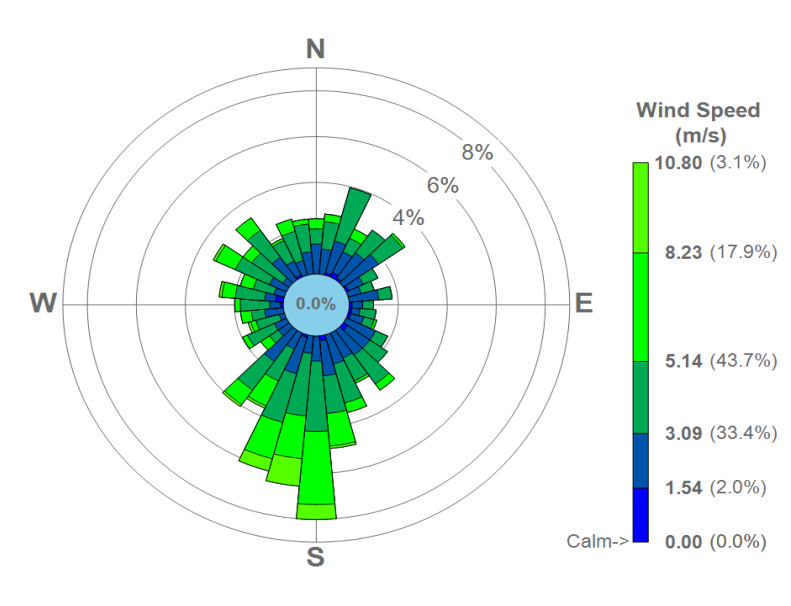
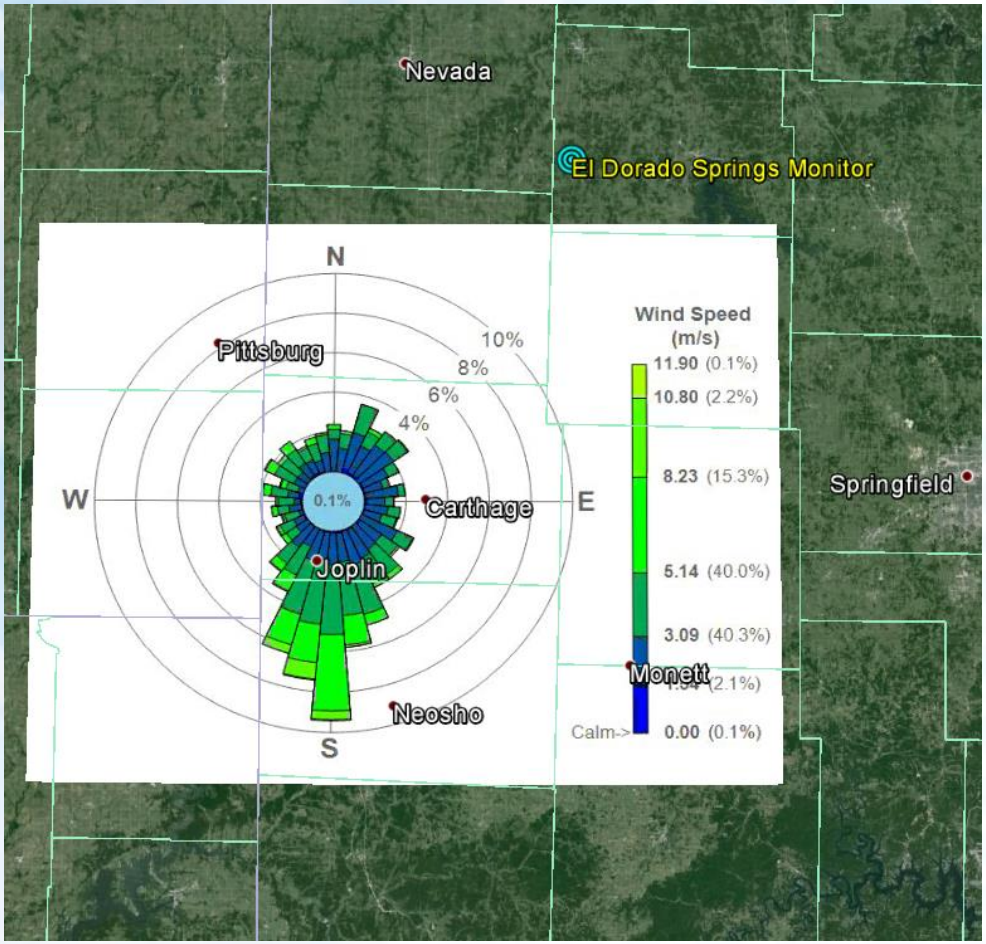
Case Study: Wind Analysis

- Narrowed data by putting emphasis on winter season months
  - Cooler temperatures are more ideal for nitrate formation and thus, secondary $PM_{2.5}$ formation.
  - Wind roses using data from October – March for 5 years.



Case Study: Wind Analysis

- Joplin Airport closest weather station to facility
- 20% of time analyzed had wind direction between 170º (S) and 200º (SSW)
- Grove & Monett - more variation
  - Stronger SSE and NW components



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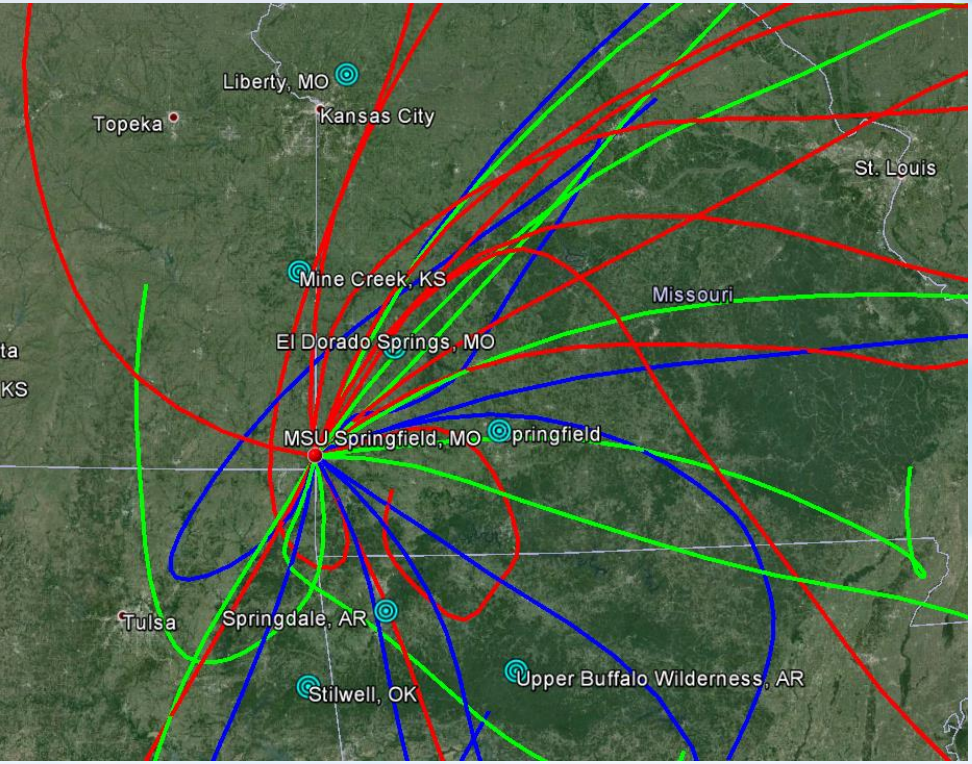
Case Study: Forward Trajectories



- Demonstrates path air parcel took from a point of origin.
- Used NOAA's HYSPLIT Model.
- Image of December 2013 trajectories.
- 13% (4 days) air advected within 17º sector of El Dorado Springs monitor.

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Case Study: Forward Trajectories

- Findings:
  - Top 3 monitors with most trajectory hits from October 2013 – March 2014:
    - Liberty, MO = 20 (11%)
    - El Dorado Springs, MO = 17 (9.3%)
    - Stilwell, OK = 13 (7.1%)
- Determined Liberty, MO monitor not representative of concentrations near proposed plant due to close proximity to densely populated Kansas City.

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Case Study: Back Trajectories

- Demonstrates path air parcels have taken prior to arriving at monitor site.
- Again used NOAA's HYSPLIT (Hybrid Single Particle Lagrangian Integrated Trajectory Model).
- Only used cold season days when the monitor showed exceedance of 12 $\mu g/m^3$ (annual NAAQS primary $PM_{2.5}$ standard)
  - Information from EPA Air Quality website
  - El Dorado Springs = 8 exceedances, 0 hits within 10 km
  - Liberty = 17 exceedances, 1 hit
  - Stilwell = 10 exceedances, 0 hits

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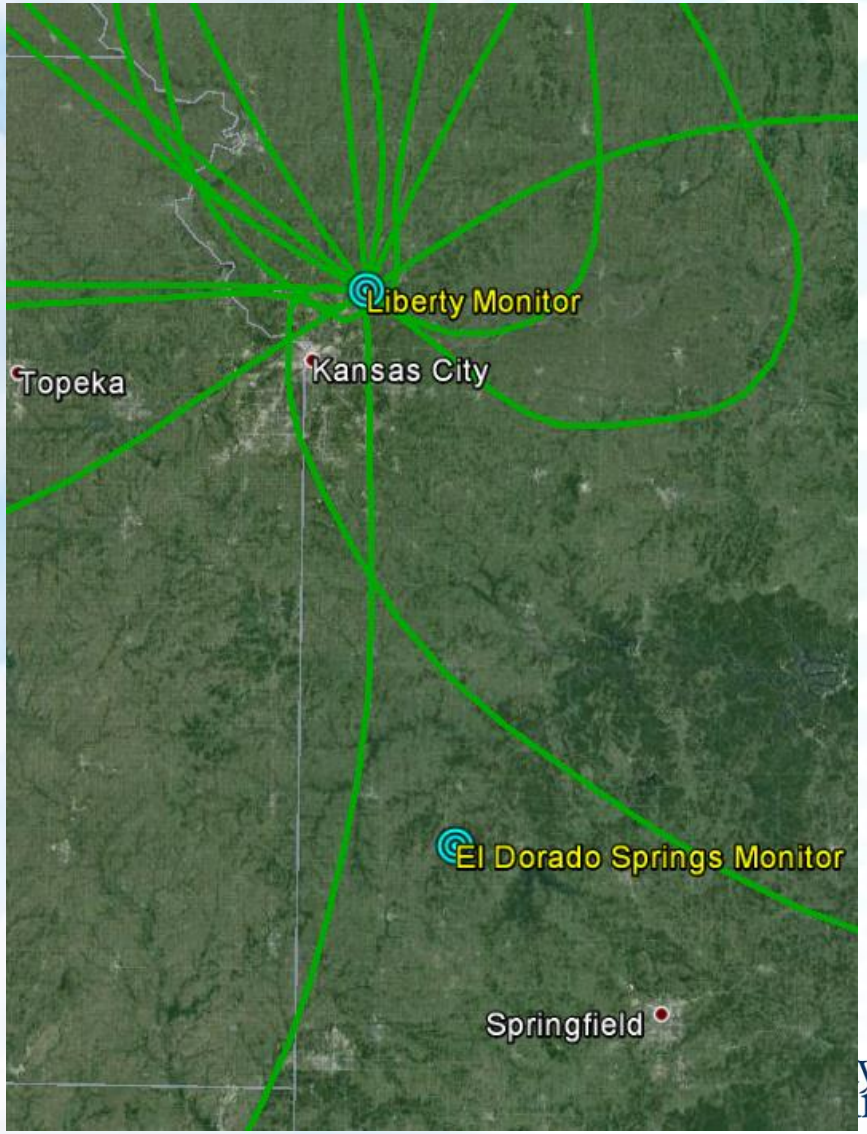
Case Study: Back Trajectories



Case Study: Demographics

> Is monitor location similar to plant location?

Monitoring stations and local population centers.

Monitor Name	Nearest Town	Distance to Nearest Town (km)	Population	Distance to Proposed Plant (km)
Proposed Plant	Galena, KS	0.30	3,085	0
El Dorado Springs	Jerico Springs, MO	8	228	84
Liberty	Liberty, MO	7	29,149	248
Stilwell	Cherry Tree, OK	Within city limits	883	146

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Case Study: Surrounding Sources

- Received county level emission rates of NO_x, SO_2, Ammonia and $PM_{2.5}$ from MDNR & KDHE

Table 5. Annual point source and non-point source emission rates from the surrounding counties.

County	NO_x Emission Rate (TPY)	SO_2 Emission Rate (TPY)	Ammonia Emission Rate (TPY)	Direct $PM_{2.5}$ Emission Rate (TPY)
Barton	468.61	35.87	1711.48	1135.74
Cedar	198.27	3.30	596.99	502.85
Jasper	2190.50	9047.63	1619.33	2392.44
Lawrence	405.10	8.22	2534.56	1028.04
Newton	414.89	15.28	3906.44	1647.21
Cherokee	155.25	0.25	0.00	0.77
TOTAL	**3832.62**	**9110.55**	**10368.80**	**6706.28**

- Compare project PTE to regional actual emissions.
  - NO_x = 1.4%
  - SO_2 = 2.8%
  - Direct $PM_{2.5}$ = 1.6%

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Case Study: Final Argument for Monitor of Choice

- Location
  - 84 km northeast of facility
    - Far enough distance to allow secondary $PM_{2.5}$ formation
    - Close enough to experience similar weather conditions
- Wind & Trajectory Analysis
  - South and southwest winds common near Joplin
  - Advect air toward monitor
- Data Quality
  - Monitor data would be of similar quality to that of a site specific monitor
  - Deployed by the state/local air monitoring stations (SLAMS), reports to Missouri Laboratory Services Program

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A Case Study - Part 2

Quantifying Secondary $PM_{2.5}$ as part of Demonstrating Compliance with NAAQS & PSD Increments

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Case Study: How to Quantify Secondary $PM_{2.5}$

- AERMOD can only be used to find primary (direct) $PM_{2.5}$ emissions, not secondary $PM_{2.5}$ emissions
- How to quantify secondary $PM_{2.5}$ emissions?
  - Cross-State Air Pollution Rule (CSAPR)
  - Pollutant offset ratios suggested by the National Association of Clean Air Agencies (NACAA) in May 2014 guidance

Case Study: Cross-State Air Pollution Rule (CSAPR)

- Rule works to improve air quality by reducing power plant emissions contributing to ozone and PM in other states.
- CSAPR utilizes CAMx, a photochemical model, to quantify impacts of SO_2 and NO_X emissions on the annual and 24-hr $PM_{2.5}$ concentrations at ambient monitoring locations around U.S.
- Source: http://www.epa.gov/crossstaterule/techinfo.html

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Case Study: Cross-State Air Pollution Rule (CSAPR)

- Use CSAPR data to find 2014 base and control case data in MO for annual and 24-hr $PM_{2.5}$ design values.

Pollutant	2014 Base Case Emissions (tpy) [1]	2014 Control Case Emissions (tpy) [1]	Variation in Emissions (tpy)
SO_2	511,664	308,275	203,388
NO_x	357,846	352,631	5,216
Total	869,510	660,906	208,604

- Find response factor to calculate concentration of $PM_{2.5}$ design value per ton of NO_x and SO_2 per year.

Site ID	Monitoring Site [2]	State	County	Annual $PM_{2.5}$ Design Values ($\mu g/m^3$) [3]			24-Hour $PM_{2.5}$ Design Values ($\mu g/m^3$) [3]		
				2014 Base Case Concentration	2014 Control Case Concentration	Concentration Variation	2014 Base Case Concentration	2014 Control Case Concentration	Concentration Variation
29-039-0001	El Dorado Springs	MO	Cedar	9.94	8.85	1.09	24.1	20.7	3.4

Site ID	Monitoring Site[4]	Total SO_2 & NO_x Emissions Variation (tpy)	Annual $PM_{2.5}$ Design Value Variation ($\mu g/m3$)	24-hr $PM_{2.5}$ Design Values Variation ($\mu g/m3$)	Annual $PM_{2.5}$ Design Value Response Factor ($\mu g/m3$ tpy)	24-hr $PM_{2.5}$ Design Value Response Factor ($\mu g/m3$ tpy)
29-039-0001	El Dorado Springs	208,604	1.09	3.4	5.23E-06	1.63E-05

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Case Study: Cross-State Air Pollution Rule (CSAPR)

- The response factor was multiplied by the proposed project's total SO_2 and NO_x PTE values to find estimated impact on secondary formation of $PM_{2.5}$ at monitor.

Estimated Impacts of the Proposed Project on Secondary Formation of $PM_{2.5}$

Pollutant	Project Emissions Increase (tpy)	Annual $PM_{2.5}$ Response Factor ($\mu g/m^3$ tpy)	Anticipated Annual $PM_{2.5}$ Source Impact ($\mu g/m^3$)	24-hr $PM_{2.5}$ Response Factor ($\mu g/m^3$ tpy)	Anticipated 24-hr $PM_{2.5}$ Source Impact ($\mu g/m^3$)
SO_2	250	5.23E-06	1.31E-03	1.63E-05	4.08E-03
NO_x	55		2.86E-04		8.93E-04
Total	-	-	0.002	-	0.005

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Case Study: Cross-State Air Pollution Rule (CSAPR)

- Impacts of combined primary and secondary $PM_{2.5}$ on NAAQS analysis.

Averaging Period	NAAQS ($\mu g/m^3$)	Max Modeled Primary $PM_{2.5}$ Impact ($\mu g/m^3$)	Estimated Secondary $PM_{2.5}$ Impact ($\mu g/m^3$)	Background Concentration ($\mu g/m^3$)	Total Max $PM_{2.5}$ Impact ($\mu g/m^3$)	Exceed NAAQS?
24-hr	35	XX	0.005	XX	XX	No
Annual	12	XX	0.002	XX	XX	No

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Case Study: Pollutant Offset Ratio

- Guidance provided by the NACAA: Finds estimate of emission rate
  - Pollutant offset ratios of 40:1 for SO_2 and 200:1 for NO_x

$$\text{Secondary } PM_{2.5} \text{ Emissions} = \left(\frac{NO_x(tpy)}{200}\right) + \left(\frac{SO_2(tpy)}{40}\right)$$

  - Result = 1.49 lb/hr of secondary $PM_{2.5}$
  - Use screening model (SCREEN3) to assess downwind impact of emission rate
    - Enter stack information, meteorology and terrain options
    - Does not account for chemical reactions in formation of $PM_{2.5}$ just gives estimate of downwind concentration.
    - Result = 2.93 μg/m^3 approximately 2,506 m from source.

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Case Study: Pollutant Offset Ratio

$$\text{Secondary PM}_{2.5}\text{ Emissions} = \left(\frac{NO_x(tpy)}{200}\right) + \left(\frac{SO_2(tpy)}{40}\right)$$

- Regional emissions of NO_x and SO_2 are known so used offset ratios to also find secondary $PM_{2.5}$ emissions from region.
- Compared those findings to proposed project's expected emissions.
- Findings: Proposed project would contribute ~2.8% of total regional secondary $PM_{2.5}$ emissions.

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Case Study: Secondary $PM_{2.5}$ Analysis for PSD Permit Conclusions

- Using both CSAPR and Pollutant Offset Ratio methods showed low amounts of secondary $PM_{2.5}$ formed from NO_x and SO_2
- Maximum impacts from primary and secondary $PM_{2.5}$ would not occur at same time & location, unlikely secondary $PM_{2.5}$ would result in violation of NAAQS
- Compared secondary $PM_{2.5}$ value found from pollutant offset ratios to regional values obtained from MDNR
  - Our facility contributes about 3% to the total regional value

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Case Study: Feedback from Agency

- This type of analysis is only the second of its kind to be submitted to the state of Missouri.
- First was also a Trinity project submitted several months before this one.
- MDNR had “95% approved” the similar analysis.

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Questions?

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