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Air quality & sources affecting $PM_{2.5}$ levels in the City of Red Deer

AWMA CPANS Edmonton Luncheon
University of Alberta Faculty Club, Edmonton, AB
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Red Deer air quality targeted by province

Report in September confirmed what many in the region already believed

By David Bell, CBC News Posted: Apr 21, 2016 6:22 PM MT | Last Updated: Apr 21, 2016 6:22 PM MT

The province announced a plan Thursday to address Re
industrial activity and vehicle emissions. (Darryl Dyck/Ca

NATIONAL POST

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Alberta on track to have worst air quality in Canada, provincial environment minister says

NP DARCY HENTON, POSTMEDIA NEWS | September 10, 2015 4:19 PM ET
More from Postmedia News

1 cbc.ca/news/canada/calgary/red-deer-air-quality-plan-1.3547830
2 news.nationalpost.com/news/world/alberta-on-track-to-have-worst-air-quality-in-canada-provincial-environment-minister-says

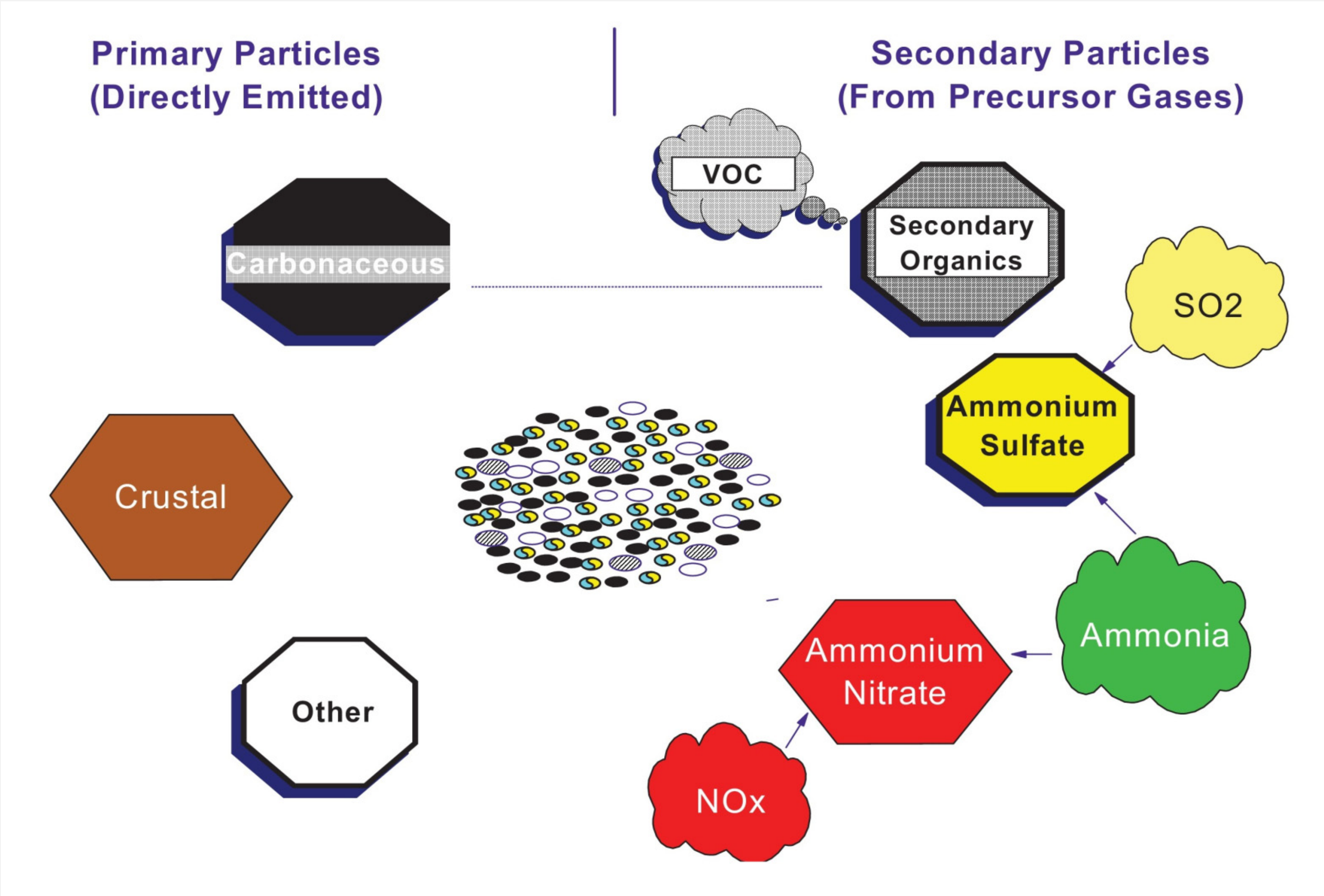
Approach

Examined sources of fine particulate matter ($PM_{2.5}$) using data for measured gases at Red Deer Riverside air monitoring station:

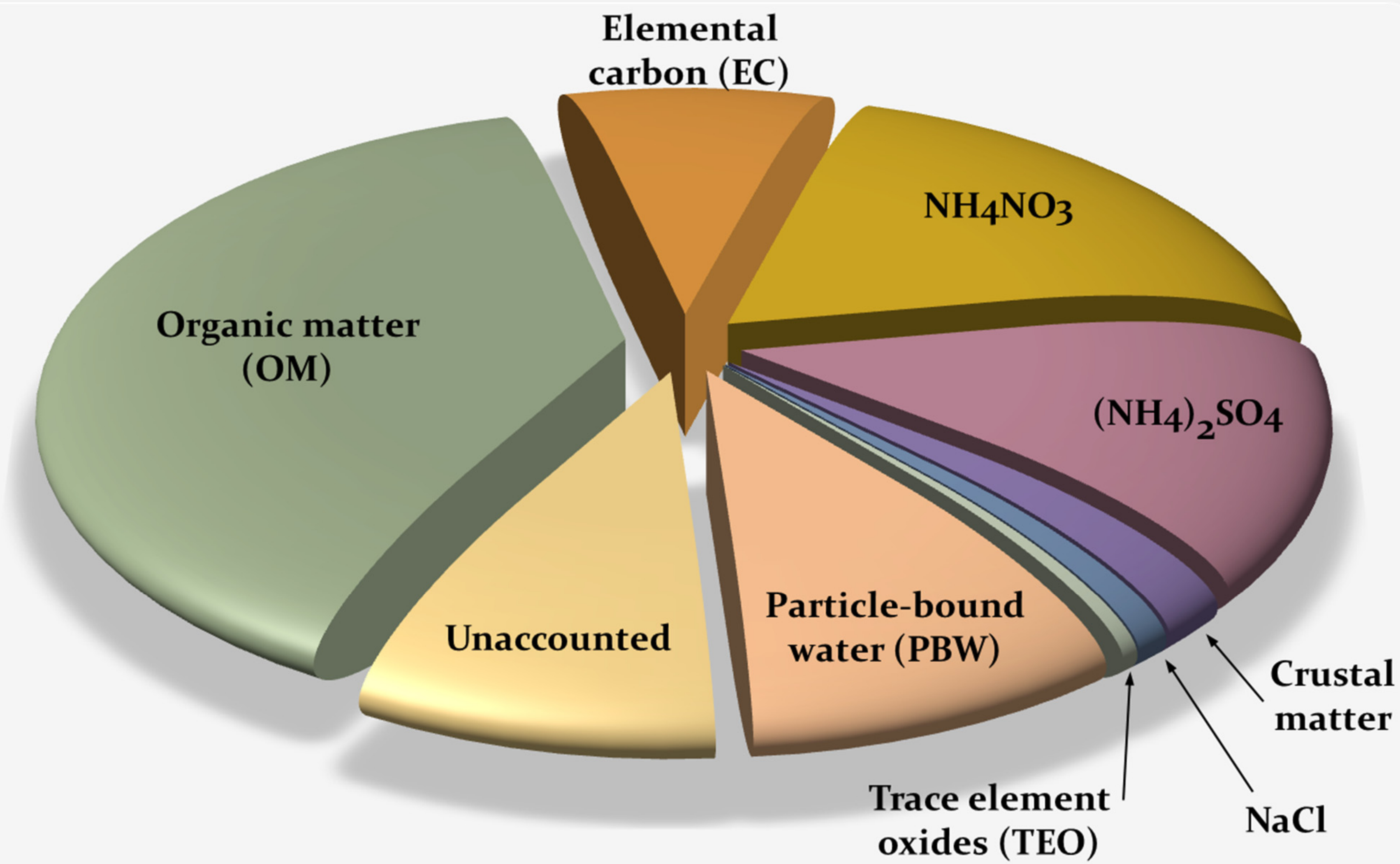
- *USEPA multivariate receptor model (EPA PMF5.0)*
- *Conditional Bivariate Probability Function (CBPF)*
- *National Oceanic and Atmospheric Administration (NOAA) HYSPLIT meteorological model for air parcel backward trajectory*
- *In-depth backward trajectory analysis for days when $PM_{2.5}$ ≥25 µg/m^3 (excluding major wildfire smoke episodes)*

- *Study independently peer reviewed & published in international journal* ***Environmental Pollution****…*
    - Bari Md.A., Kindzierski, W.B. 2017. Characteristics of air quality and sources affecting fine particulate matter ($PM_{2.5}$) levels in the City of Red Deer, Canada. *Environmental Pollution*, **221**, 367-376.

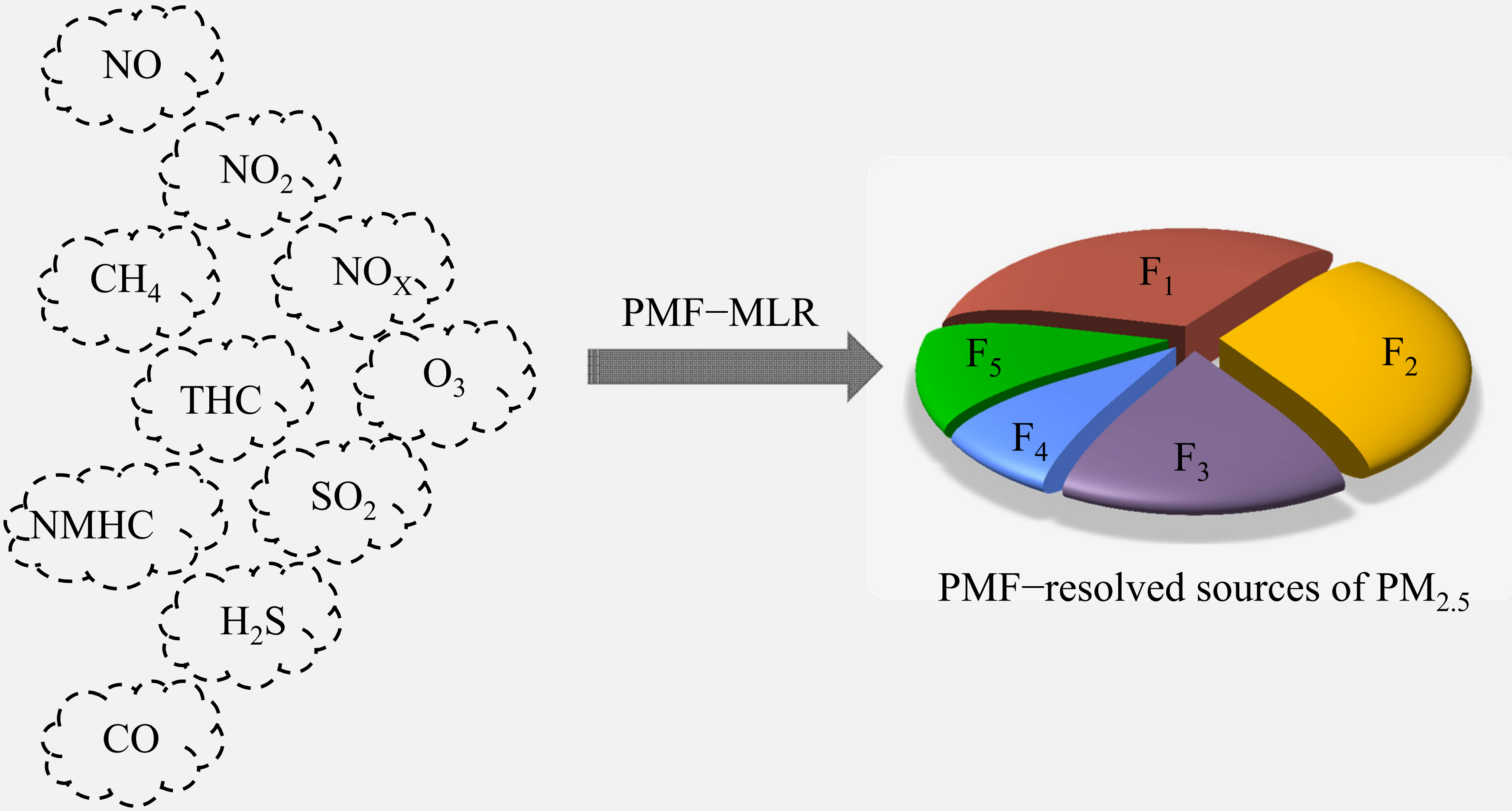
Background – What is urban $PM_{2.5}$ composed of?



General ‘analyzed’ composition of urban $PM_{2.5}$

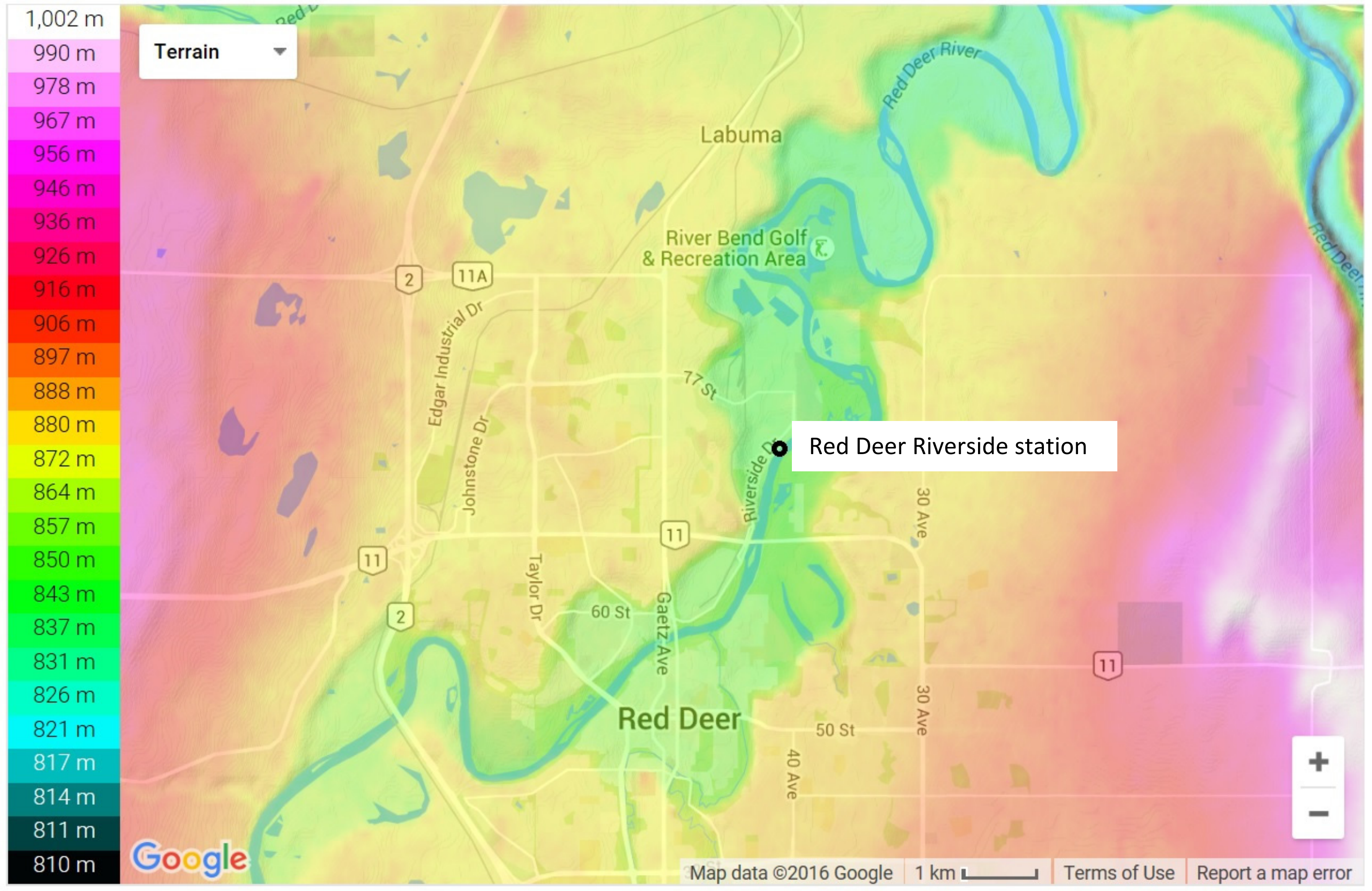


Using real-time gaseous pollutant data to identify & apportion $PM_{2.5}$ emission sources



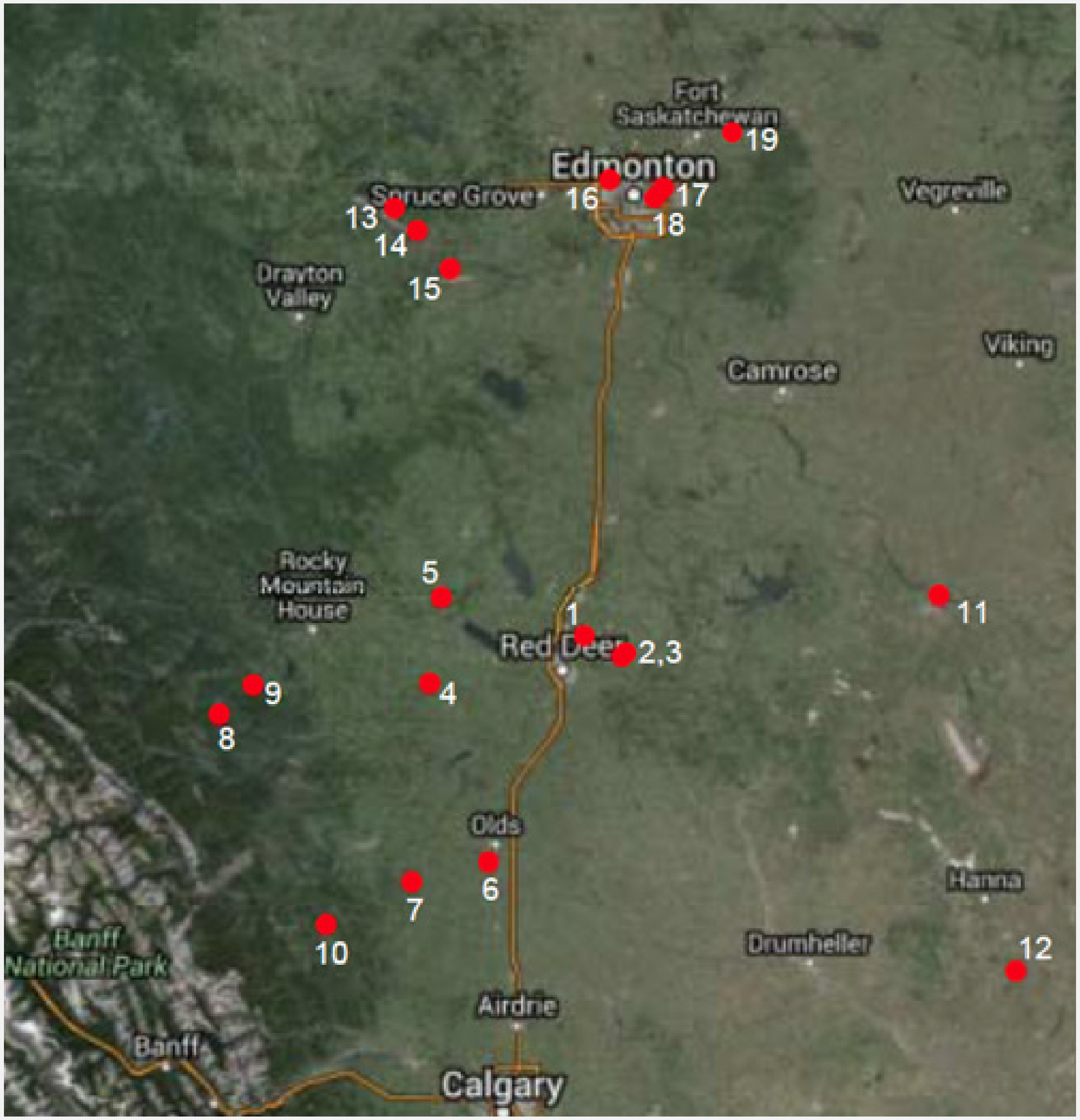
PMF−resolved sources of $PM_{2.5}$

Setting – Topographical map of Red Deer & surrounding area

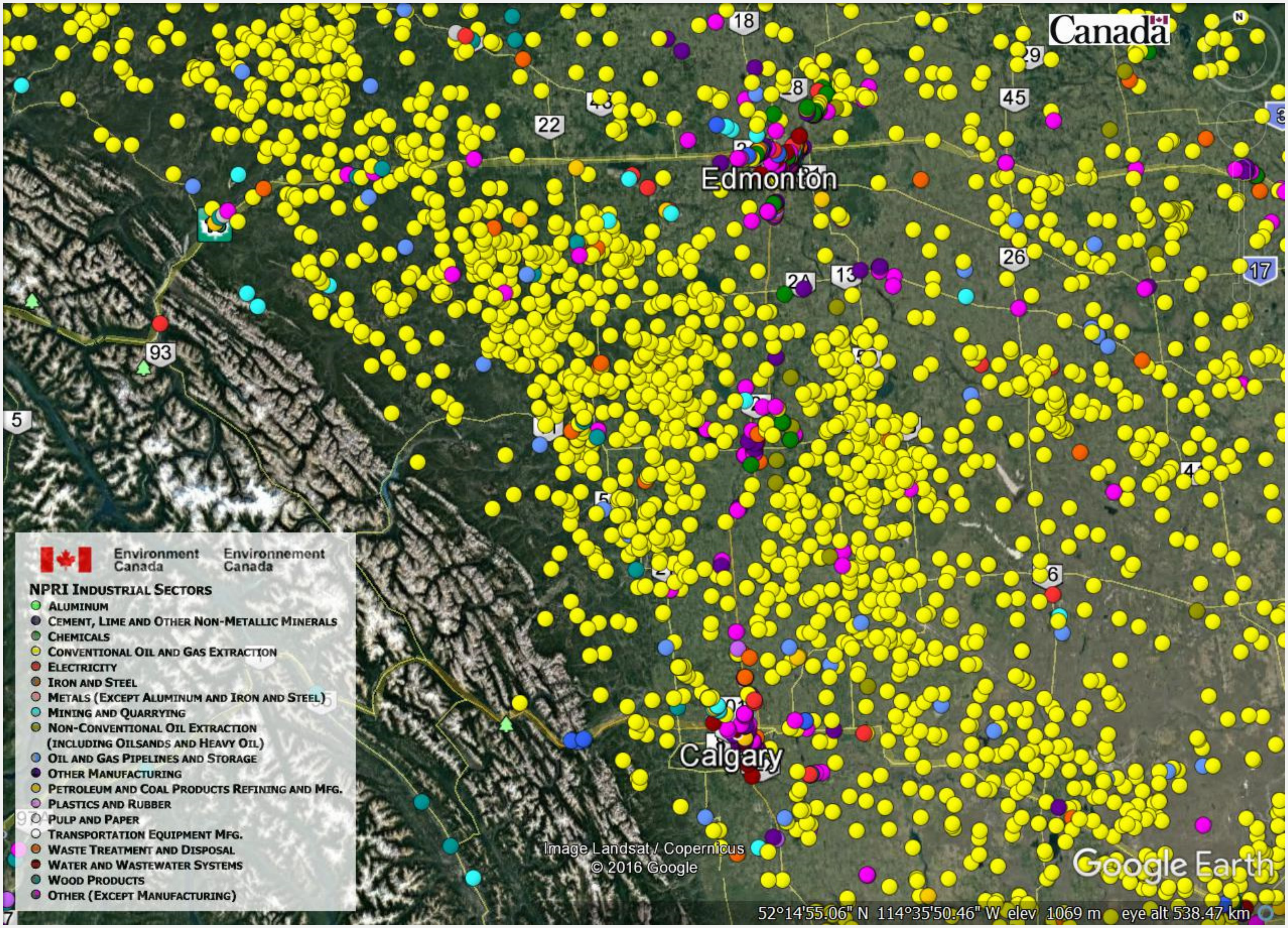


http://en-ca.topographic-map.com/places/Red-Deer-811733

Select industries in & surrounding Red Deer reporting to Environment Canada NPRI

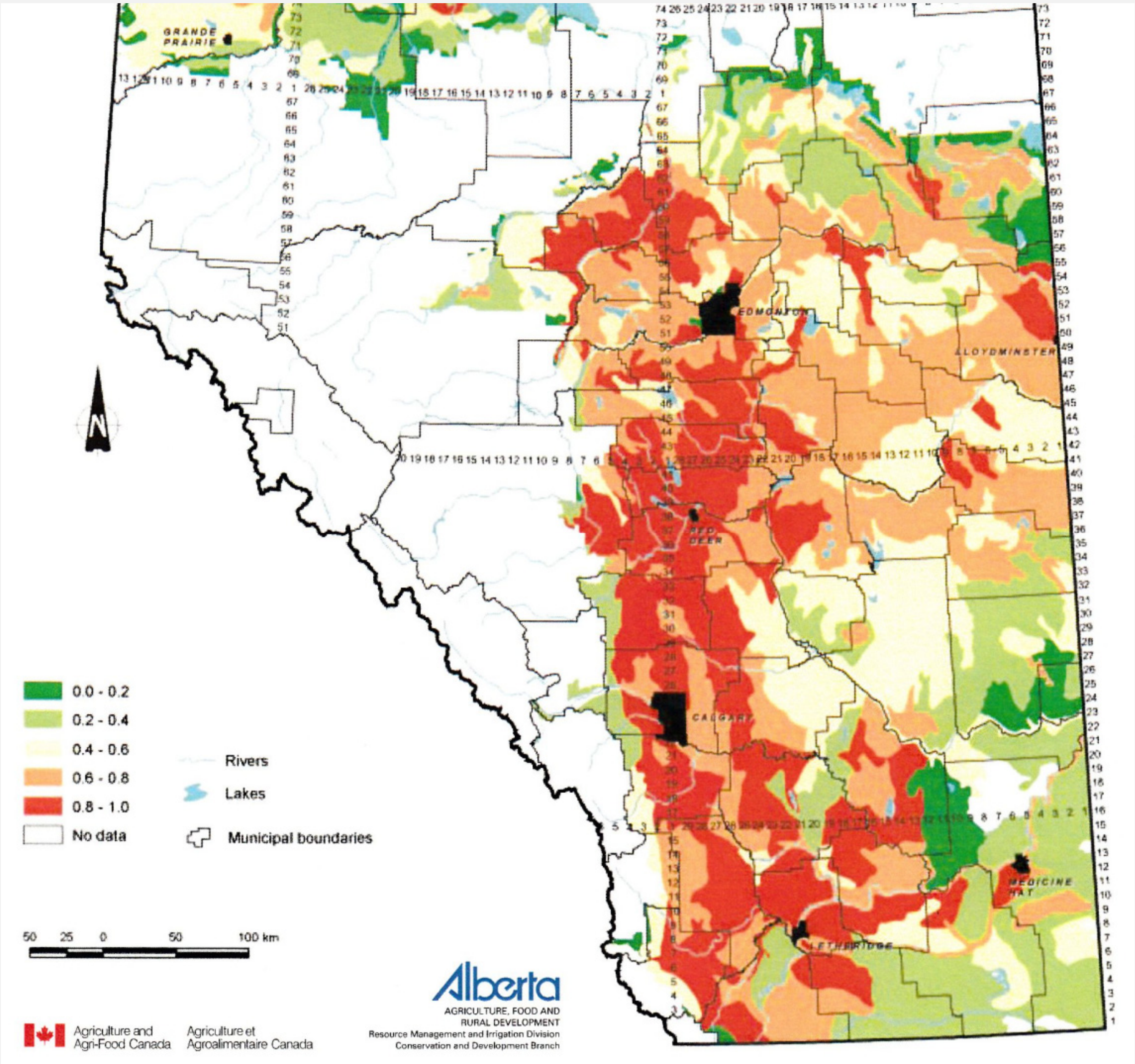


Density of conventional oil & gas extraction sources for central/south Alberta



Environment Canada NPRI & Google Earth (Image IBCAO © 2016 Google)

Manure production index for central/south Alberta



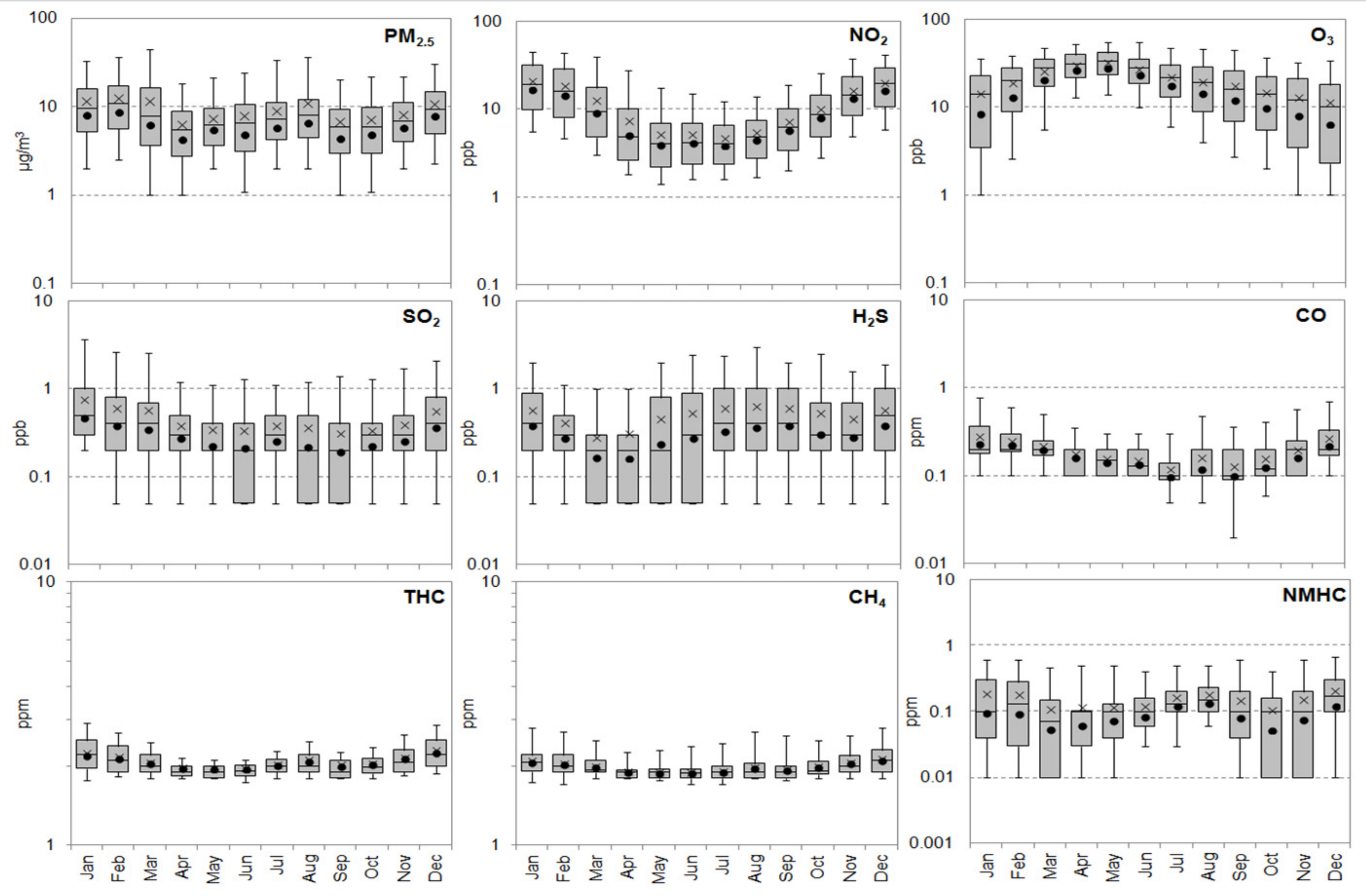
Alberta Agriculture and Forestry, 2005

2008 air emission inventory in Red Deer air zone

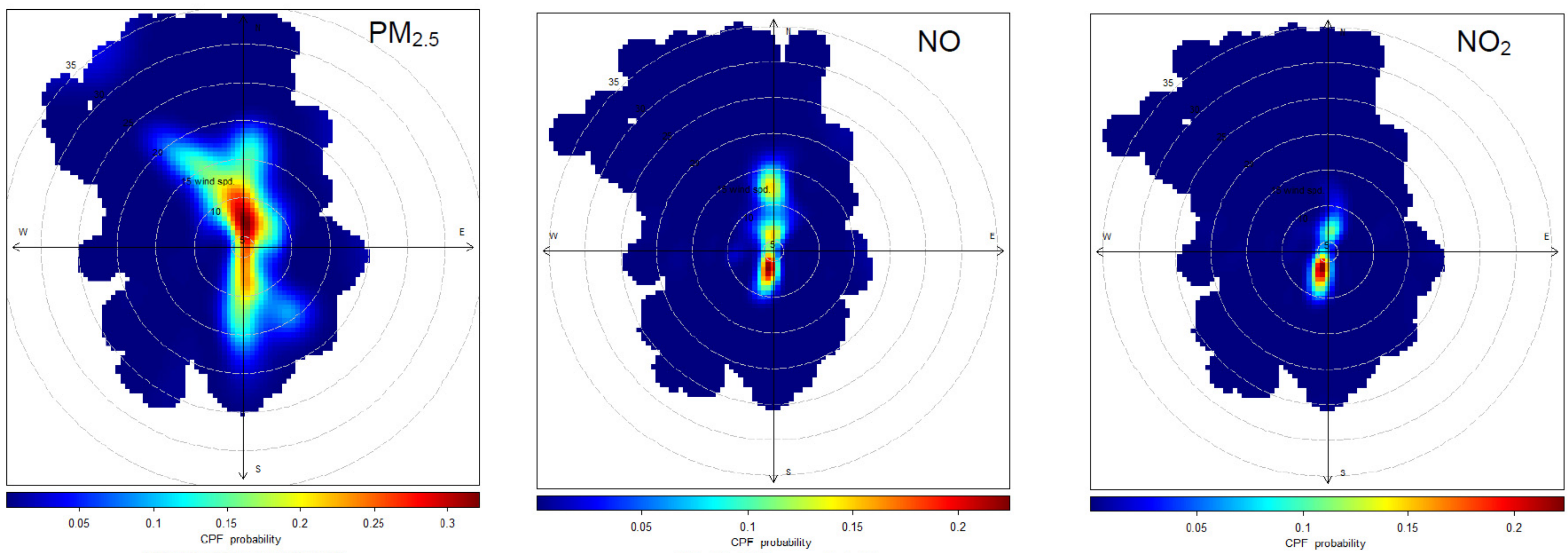
	$PM_{2.5}$ tonnes	SO_2 tonnes	NO_X tonnes	NH_3 tonnes	VOC tonnes
Agriculture	4,353	0	0	25,983	27,053
Cement and concrete	53	4	4	0	4
Chemical	481	8	2,660	3	782
Construction	9,894	0	23	0	0
Conventional oil and gas	550	62,464	62,409	383	25,423
Electrical power generation	483	10,106	21,893	6	31
Fertilizer	0	0	44	54	2
Oil sands	0	0	0	0	0
Pulp and paper	0	0	0	0	0
Road dust	23,406	0	0	0	0
Transportation	1,377	279	26,916	254	6,361
Wood products	20	15	71	20	852
Other sources	413	61	110	49	3,357
Non-industrial sources	313	122	613	6	350
Natural sources	1	0	1,322	0	189,090

Alberta Environment and Parks, 2015

Profile of hourly levels of air pollutants at Red Deer Riverside (2009–2015)



$PM_{2.5}$, NO & NO_2 conditional bivariate probability function (CBPF) plots during winter



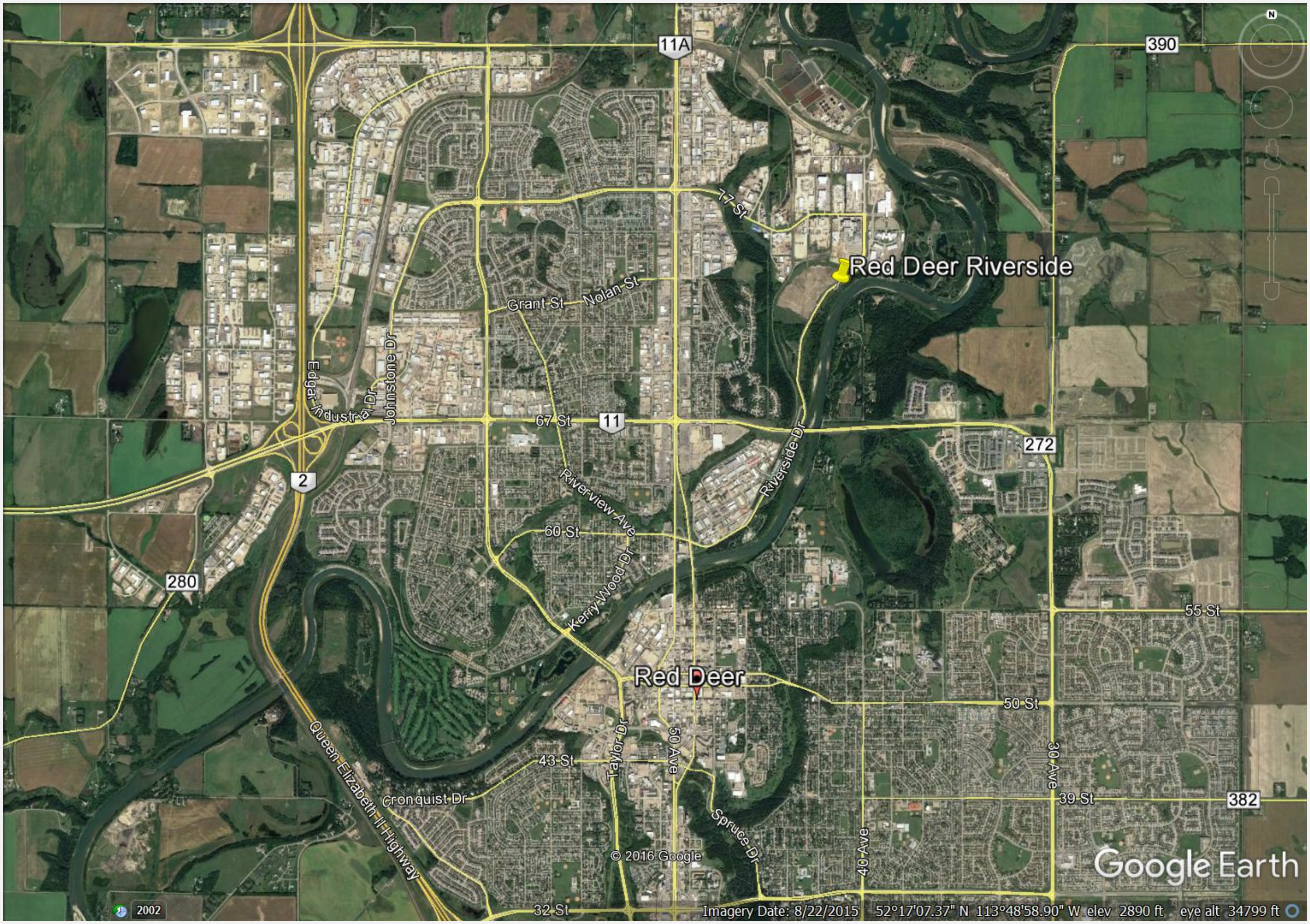
CPF at the 75th percentile (=15)

CPF at the 75th percentile (=12)

CPF at the 75th percentile (=26)

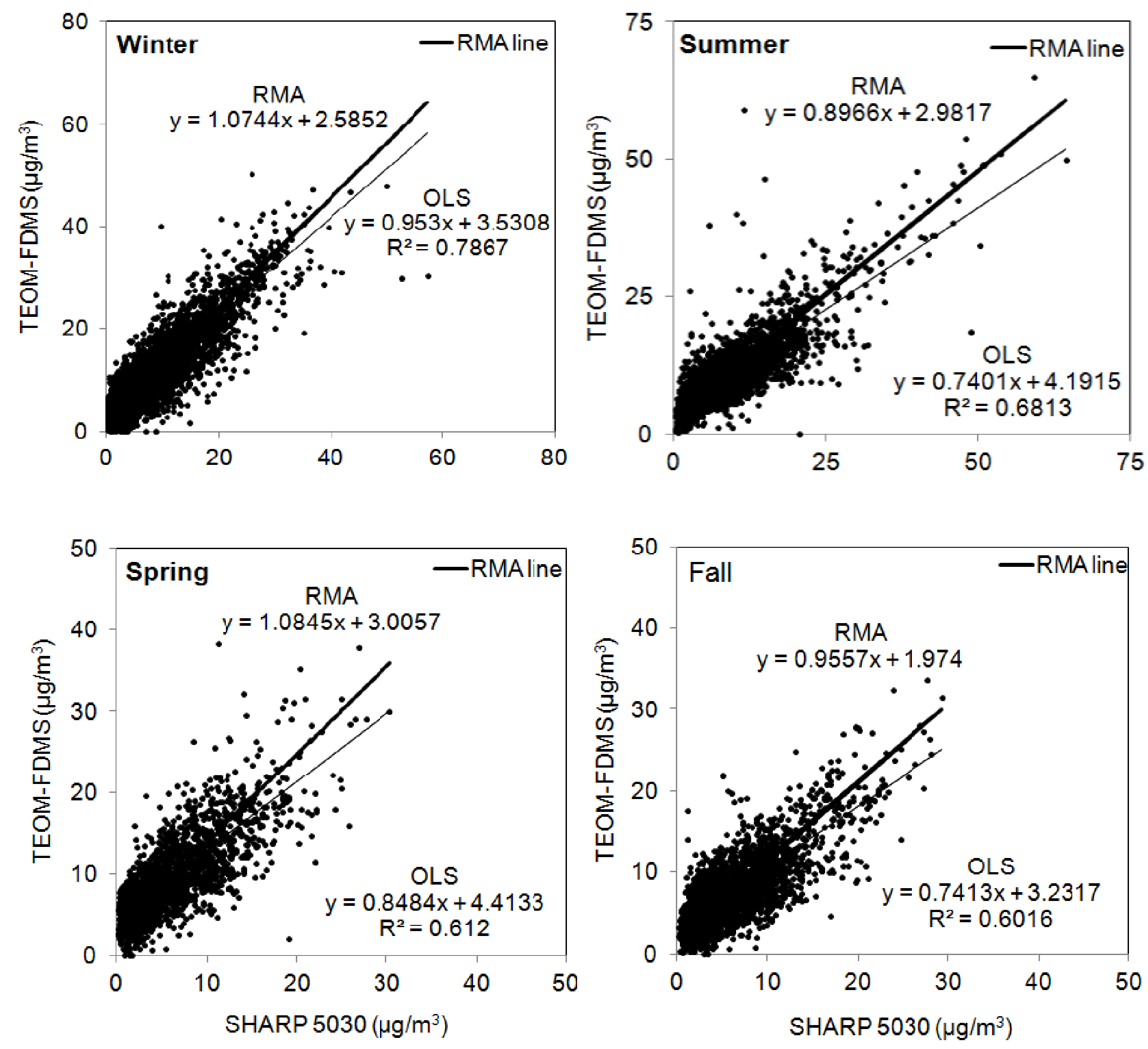
Bullseye is location of Red Deer Riverside station

Red Deer satellite map



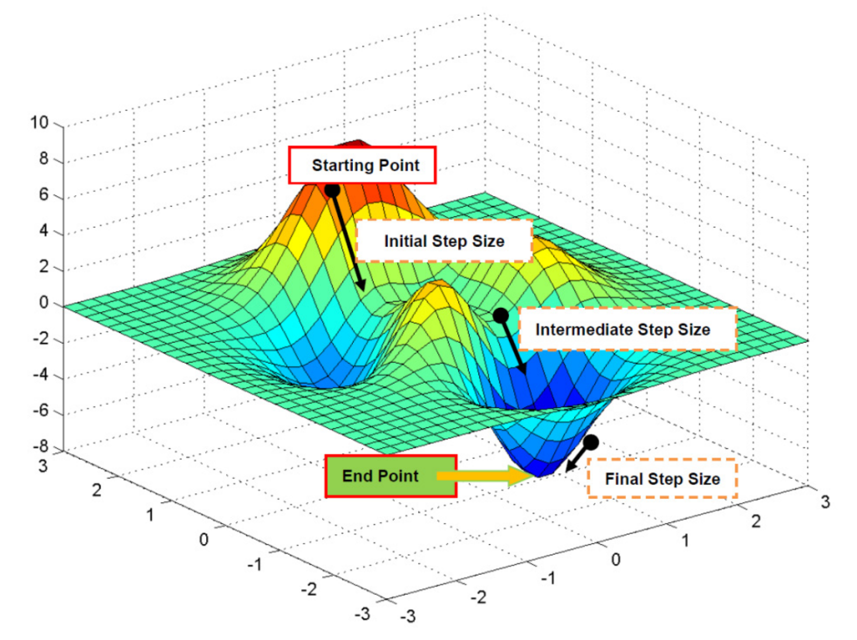
Google Earth (Image IBCAO © 2016 Google)

Comparison of hourly $PM_{2.5}$ levels from TEOM-FDMS & SHARP 5030 using reduced major axis regression (May 2009–Dec 2013)



Analysis – Positive matrix factorization (PMF5.0)

- Based on analysis of correlation between measured concentrations of chemical species in samples, assuming highly correlated compounds come from same source
- Solution derived thru iterations by minimizing a sum-of-squares object function
- May 2009–Dec 2015 dataset: 2,373 daily (24 h) data for 9 pollutants (excluded thirteen 24 h samples influenced by forest fire episodes)
- PMF solutions with 3 to 6 factors checked & 5 factor-solution chosen
- Error estimation analysis performed to understand variability & uncertainty of 4-, 5- & 6-factor solutions, and to aid in identifying the optimum solution
- MLR used to regress $PM_{2.5}$ levels against PMF-derived factor contributions

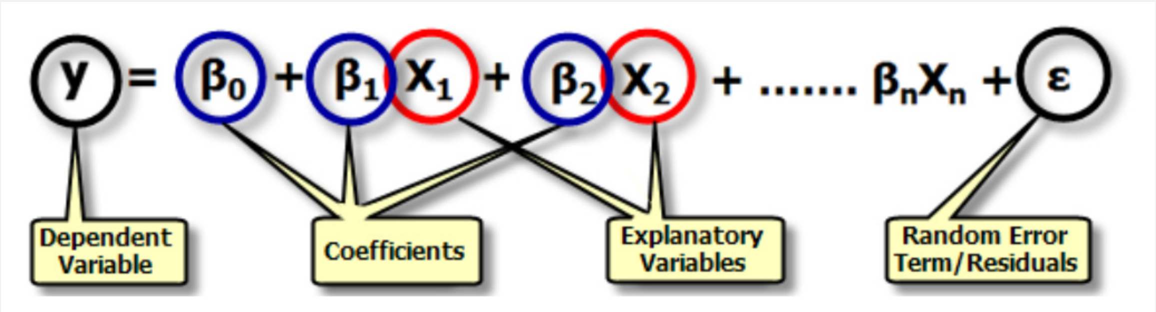


https://www.epa.gov/air-research/epa-positive-matrix-factorization-50-fundamentals-and-user-guide

Multiple linear regression (MLR)

Regressed measured $PM_{2.5}$ concentrations against factor scores obtained by PMF5.0:

- *dependent variable = daily measured $PM_{2.5}$ concentration (y)*
- *independent (explanatory) variables = daily modelled contribution of each factor from PMF5.0 output (X_i)*
- *method aids in resolving factor profiles that could be interpreted as source types*
- *regression coefficients (β_i) used to represent contribution among resolved factors to $PM_{2.5}$ over the sampled time series datasets (whole study & each season)*



Profile of PMF-derived source factors at Red Deer Riverside

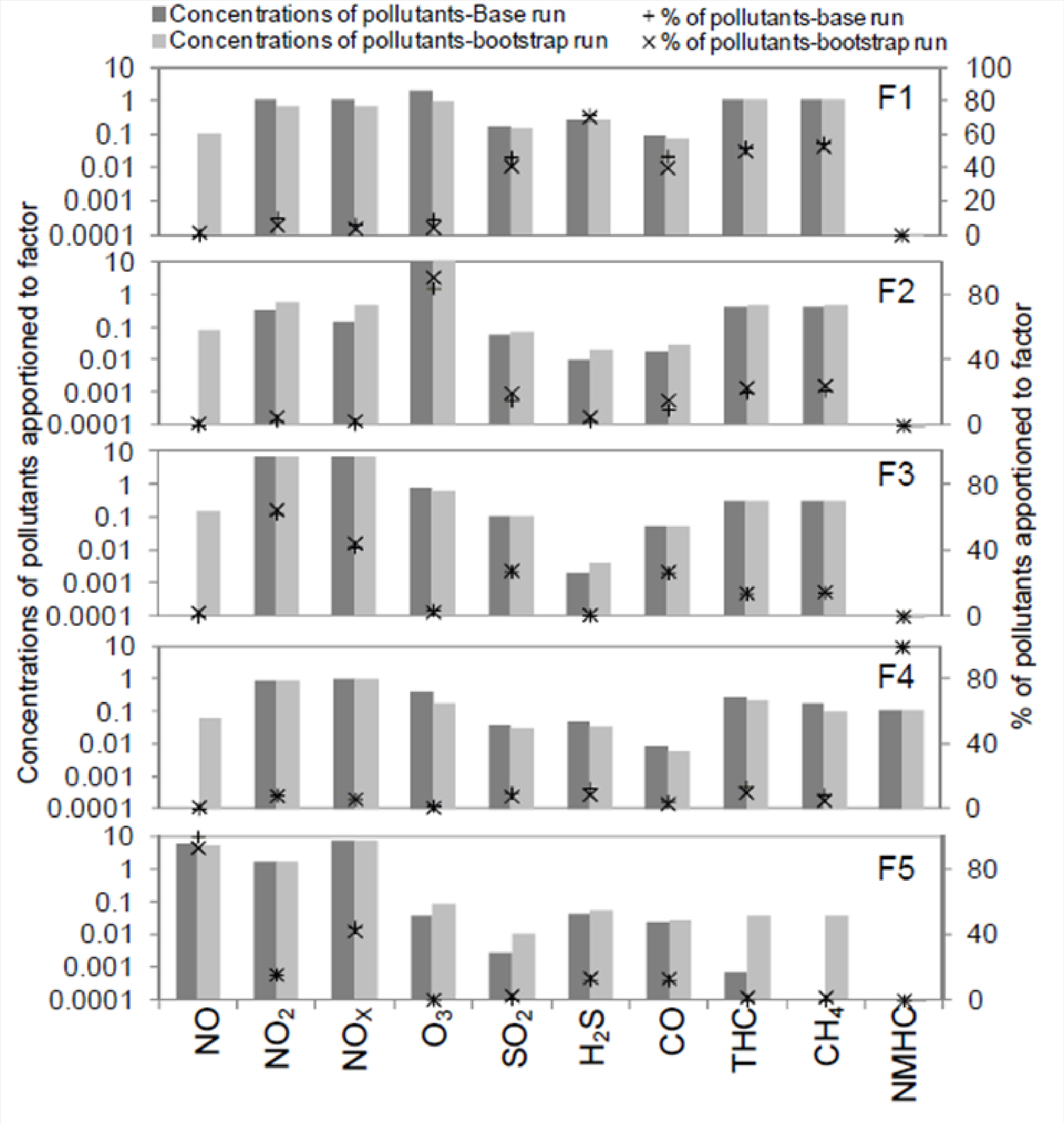
Mixed industry/agriculture

Ozone-rich (biogenic)

Traffic

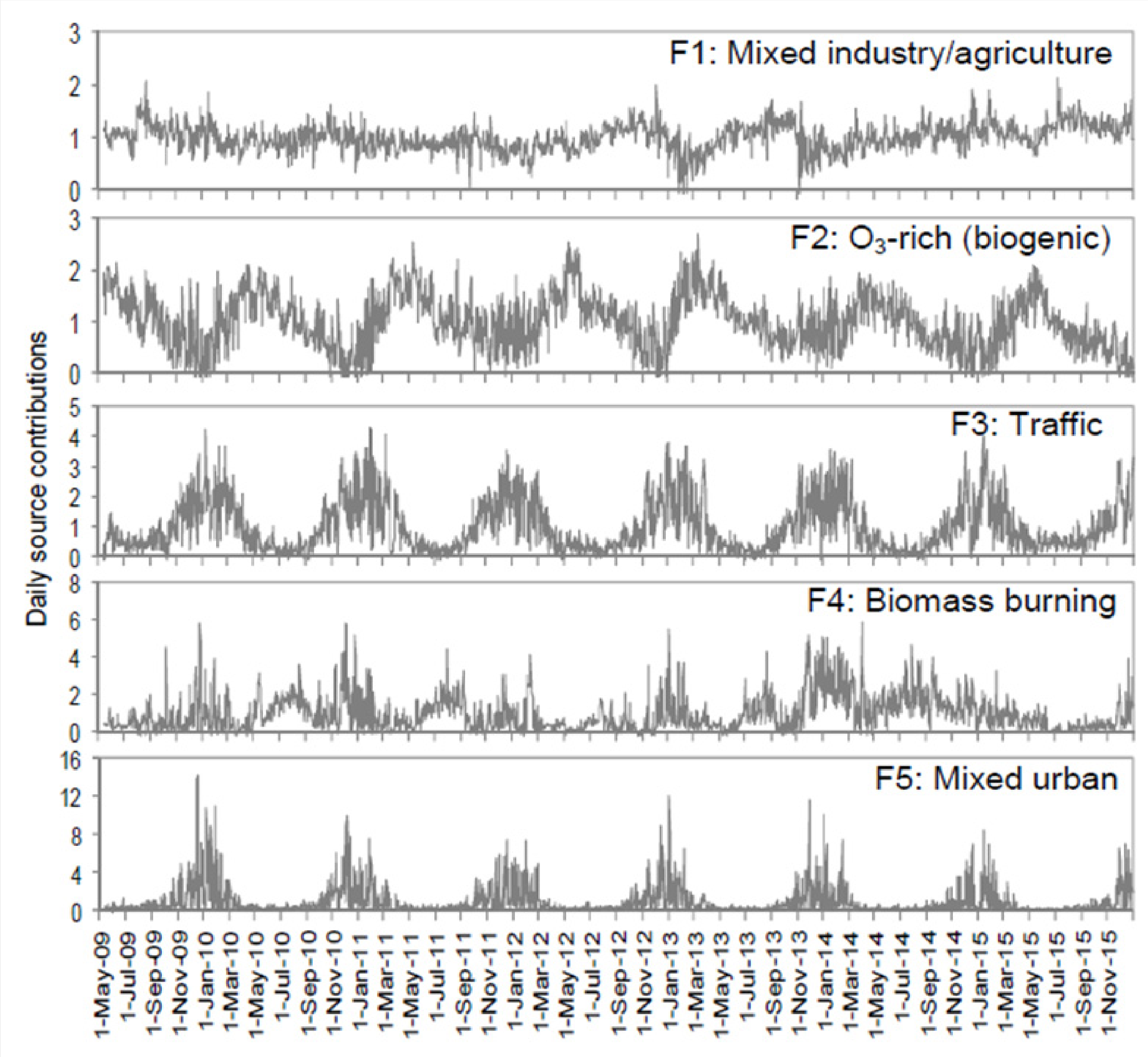
Biomass burning

Mixed urban



Bootstrapping captures the error associated with random errors

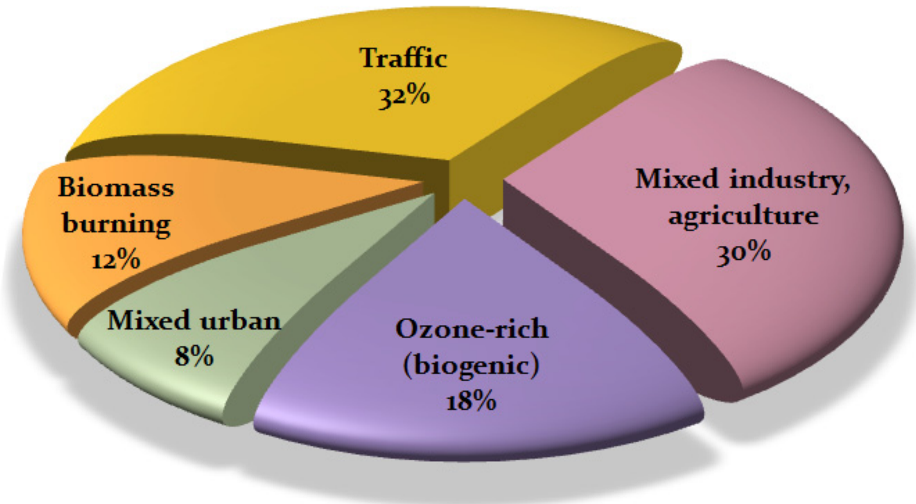
Daily contributions of PMF-derived source factors



Whole study & seasonal average contribution of each factor to measured $PM_{2.5}$ (2009–2015)

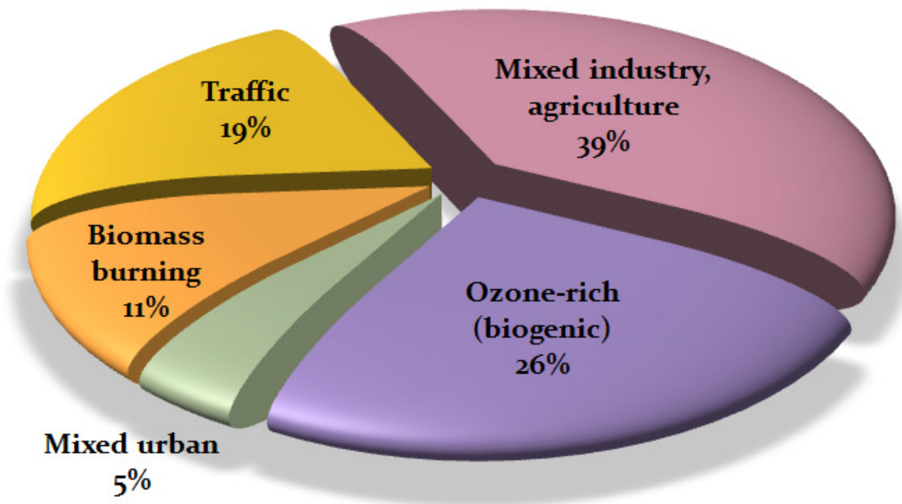
		Study period	Winter	Spring	Summer	Fall
Factor 1	Mixed industry/agriculture	39%	30%	38%	45%	45%
Factor 2	O_3-rich (biogenic)	26%	18%	39%	33%	20%
Factor 3	Traffic	19%	32%	14%	9%	22%
Factor 4	Biomass burning	11%	12%	7%	12%	8%
Factor 5	Mixed urban	4.4%	8.2%	1.9%	1.7%	4.9%

PMF−derived sources of $PM_{2.5}$ at Red Deer Riverside



Winters only

Whole study



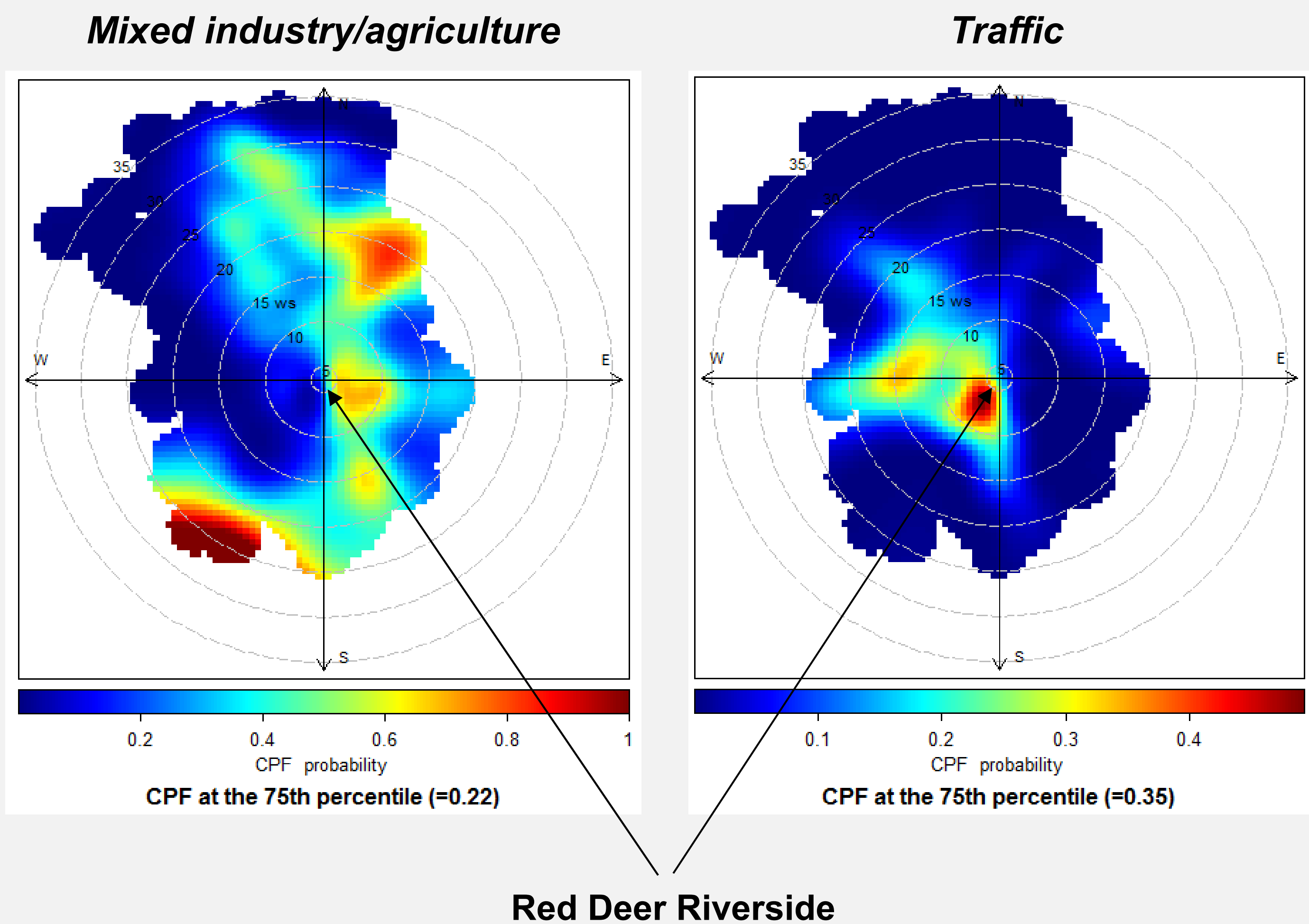
Verification analysis of PMF source assignments

- Spearman Rank correlation coefficients calculated to test strength of relationships between PMF-derived factor contribution concentrations & criteria air pollutant concentrations & meteorological data – investigate relationships identified sources & to assist in interpretation of source profiles
- Conditional bivariate probability function (CBPF) analysis – understand influence of ‘local’ emission sources for factors
- HYSPLIT backward trajectory analysis – understand influence of ‘long-range’ emission sources for factors

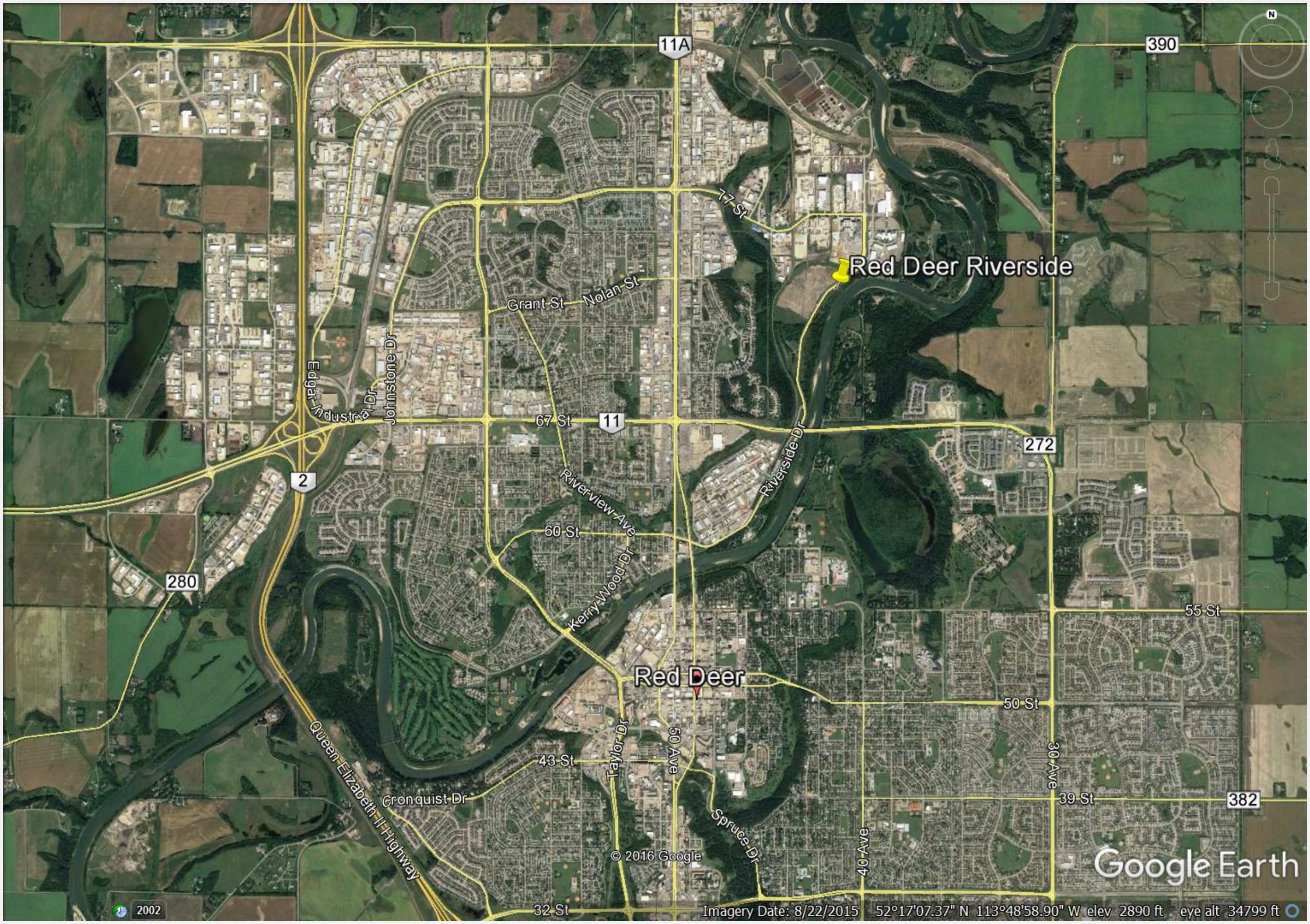
Investigation of $PM_{2.5}$ pollution–event days

- HYSPLIT backward trajectory analysis for specific $PM_{2.5}$ pollution–event days

Local source influence at Red Deer Riverside (Conditional Bivariate Probability Function plots)

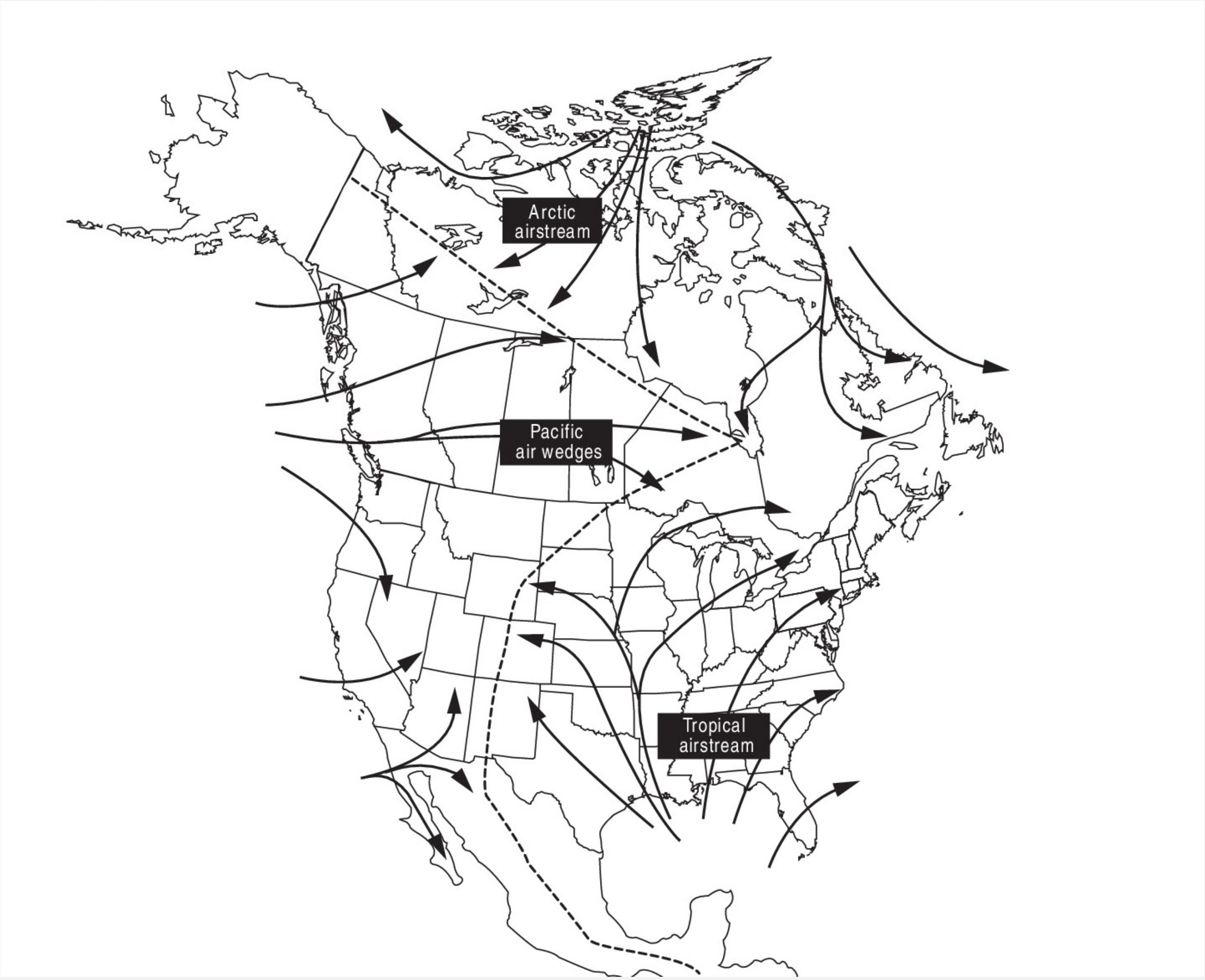


Red Deer satellite map



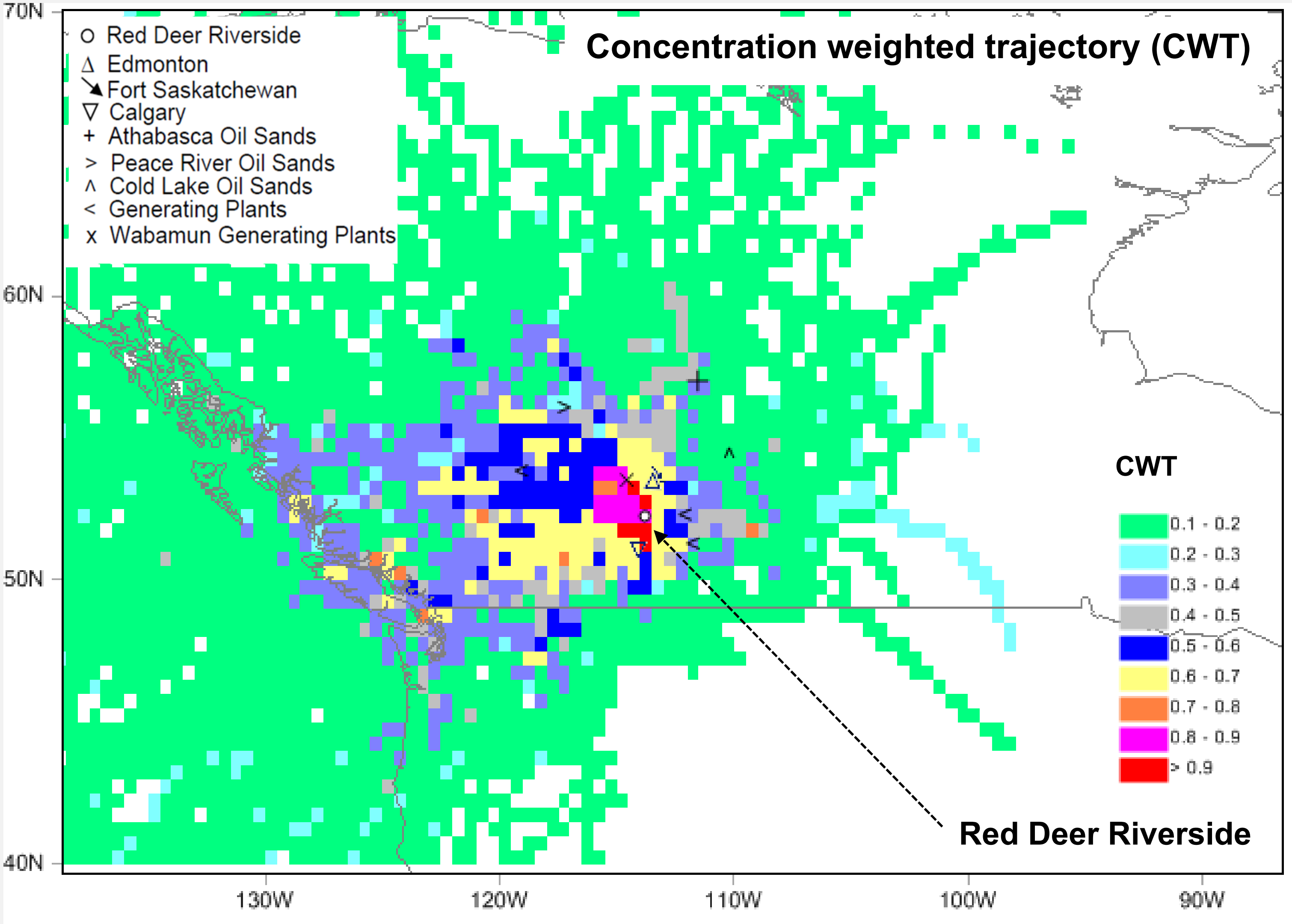
Google Earth (Image IBCAO © 2016 Google)

Long range influence – typical North American July surface wind patterns



Commission for Environmental Cooperation. 1997. Continental Pollutant Pathways. An Agenda for Cooperation to Address Long-Range Transport of Air Pollution in North America (http://www. http://www.cec.org)

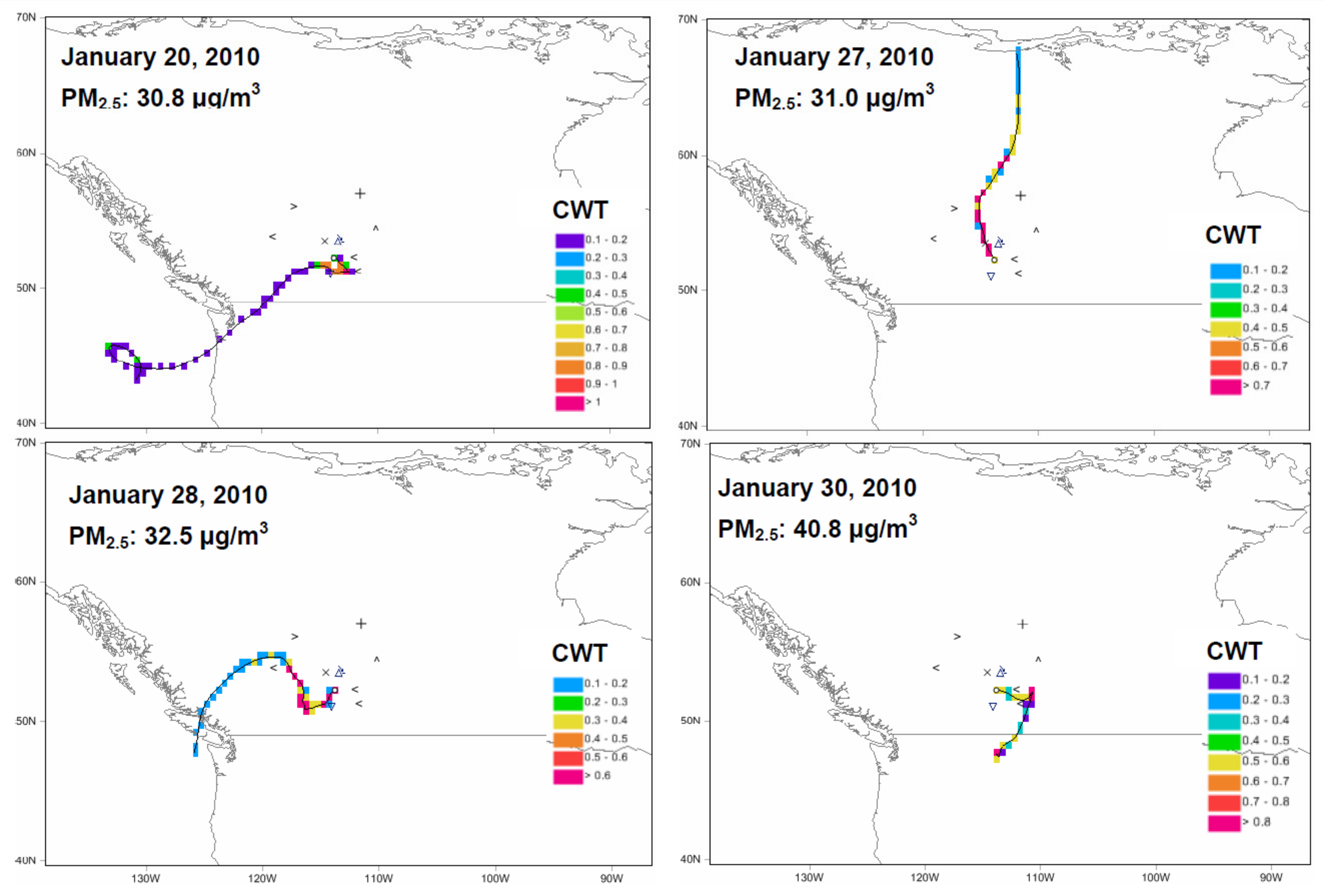
Long-range influence during winters for *mixed industry/agriculture* at Red Deer Riverside



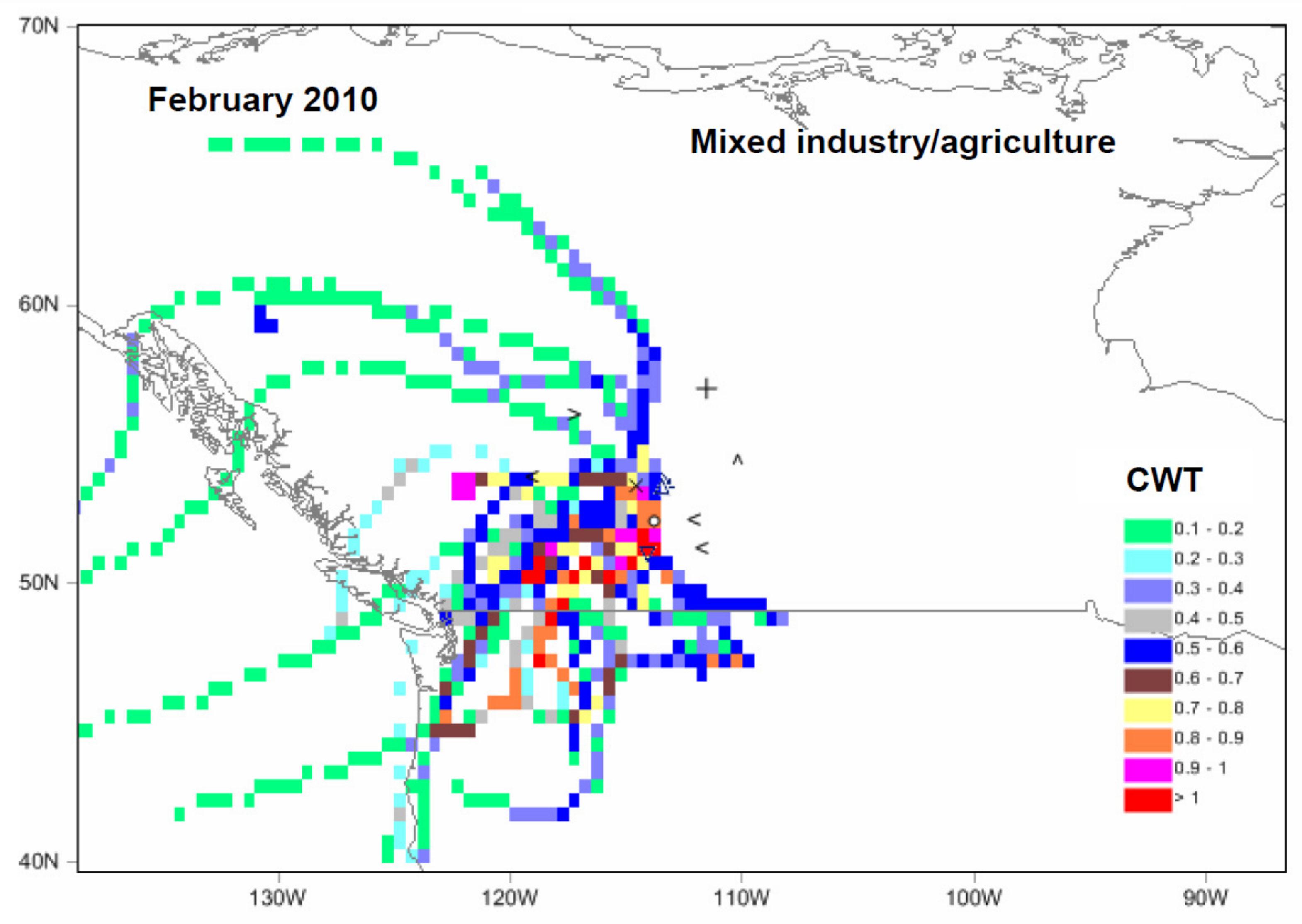
Dominant sources during $PM_{2.5}$ pollution event days at Red Deer Riverside

Date	$PM_{2.5}$ ($\mu g/m^3$)	1st	2nd	3rd
28-Dec-2009	37	Biomass burning	Traffic	Mixed industry/agriculture
5-Jan-2010	26	Mixed industry/agriculture	Traffic	
6-Jan-2010	29	Traffic	Mixed industry/agriculture	
20-Jan-2010	31	Mixed industry/agriculture	Traffic	Biomass burning
27-Jan-2010	31	Traffic	Mixed industry/agriculture	Biomass burning, mixed urban
28-Jan-2010	33	Traffic	Mixed urban	Mixed industry/agriculture
30-Jan-2010	41	Traffic	Mixed industry/agriculture	
2-Feb-2010	39	Traffic	Mixed industry/agriculture	Mixed urban
28-Feb-2010	31	Traffic	Mixed industry/agriculture	Biomass burning
1-Mar-2010	36	Mixed industry/agriculture	O_3–rich	
8-Dec-2010	34	Mixed industry/agriculture		
7-Mar-2011	25	Traffic		
8-Mar-2011	41	Traffic		
9-Mar-2011	39	Traffic		
10-Mar-2011	34	Mixed industry/agriculture	Traffic	O_3–rich
6-Feb-2013	38	O_3–rich	Mixed industry/agriculture	
5-Mar-2013	25	O_3–rich	Traffic	
8-Mar-2013	44	O_3–rich	Mixed industry/agriculture	
9-Mar-2013	32	O_3–rich	Mixed industry/agriculture	
18-Aug-2010	19	Mixed industry/agriculture	O_3–rich	Biomass burning
11-Jul-2014	28	Mixed industry/agriculture	O_3–rich	

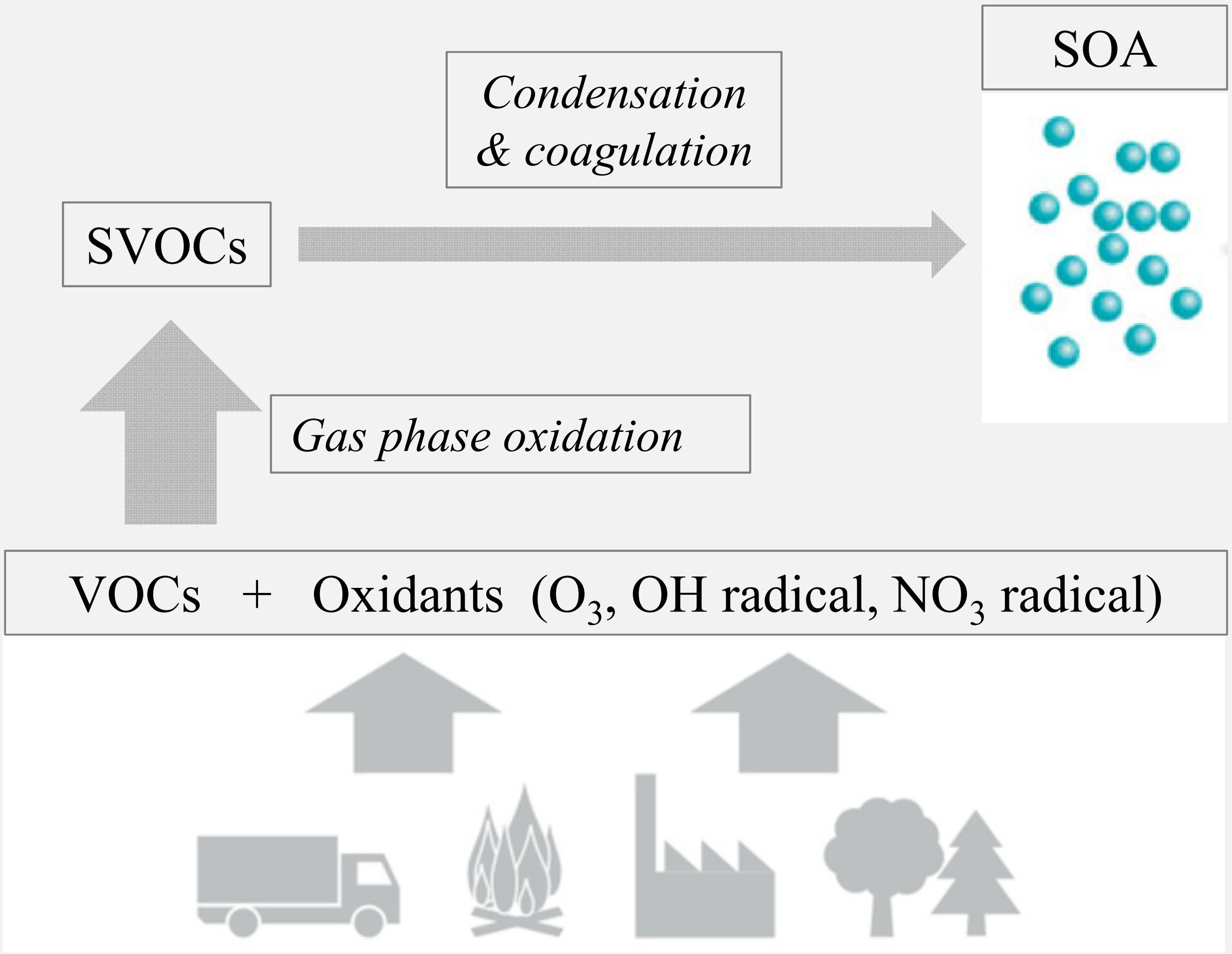
Potential source regions of mixed industry/agriculture for selected high $PM_{2.5}$ pollution event days in January 2010



Spatial distribution of CWT values for mixed industry/agriculture – all Feb 2010 days



About secondary organic aerosol (SOA)



Findings

- *Local traffic & mixed industry/agriculture were most important sources – accounting for almost two–thirds of makeup of $PM_{2.5}$*
- *Local traffic most important in winters*
- *Both local traffic & mixed industry/agriculture important for wintertime high–$PM_{2.5}$ days*
- *Biogenic emissions (hydrocarbons released by vegetation) accounted for ~one–quarter of makeup of $PM_{2.5}$*
- *$PM_{2.5}$ from biomass (wood) burning occurred over all seasons, including during winter likely from residential wood-burning appliance use*

Thank you for your attention!

Questions?