SOURCE CONTRIBUTION OF SECONDARY FINE PARTICULATE MATTER IN CENTRAL ALBERTA

Ou Nopmongcol, Jeremiah Johnson, Ralph Morris
RAMBOLL

A&WMA CANADIAN PRAIRIE AND NORTHERN SECTION (CPANS)
MAY 9, 2018

NAME CHANGE WITH EXPANDED SERVICES

ENVIRON

RAMBOLL ENVIRON

RAMBOLL

- ENVIRON merged with Ramboll and name changed in 2018
- 13,000 employees in 35 countries
- Full Environmental & Health Services
- Same experts from ENVIRON/Ramboll Environ with additional global expertise

OUTLINE

- Project Background
- Modeling Methodology
- Source Contribution Analysis
- Discussion

BACKGROUND: PARTICULATE MATTER (PM)

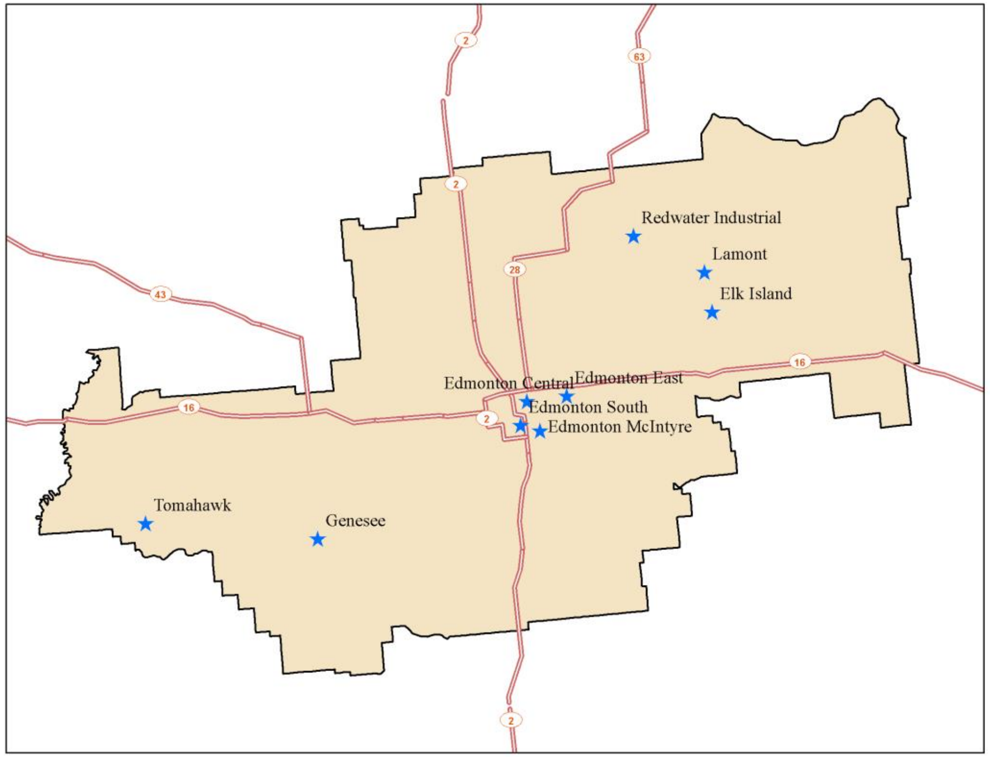
- Fine PM : diameter smaller than 2.5 μm; complex mixture consisting of *many* different *components*
- Cause health, vegetation, visibility problems
- Canadian Ambient Air Quality Standards (CAAQS)

Pollutants	Old Standards	New Standards	
		2015	2020
$PM_{2.5}$ Annual	-	10 μg/m³	8.8 μg/m³
$PM_{2.5}$ 24-hour	30 μg/m³	28 μg/m³	27 μg/m³

- Origins
  - Primary: emitted from a source
  - **Secondary**: formed through chemical and physical reactions involving different precursor gases

SO_2, NOx, NH_3, VOC → NH_4 SO_4, NH_4 NO_3, OM

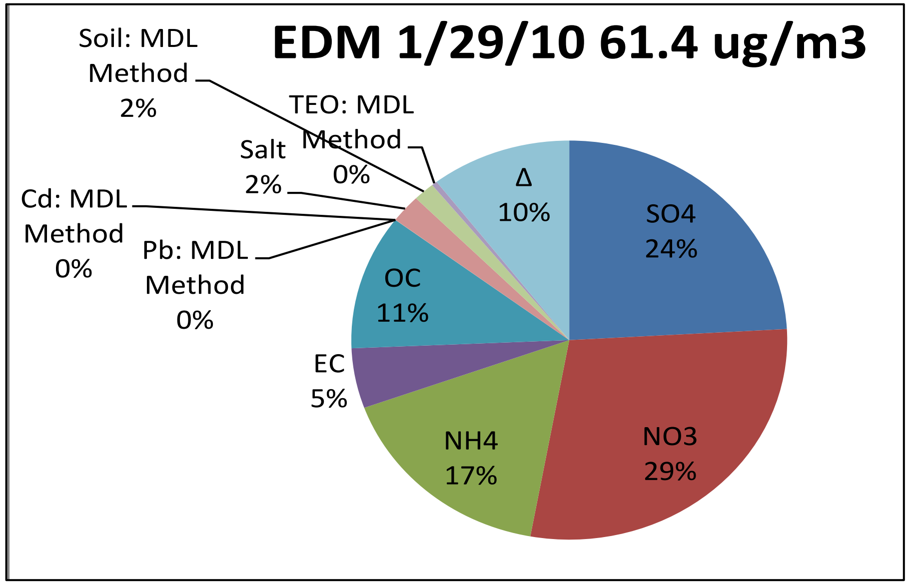
BACKGROUND: HIGH $PM_{2.5}$ IN CAPITAL REGION



24-hr average > 30 µg/m³

- 2010 : **41** exceedance days; only 4 due to fires
- Winter episodes characterized by higher than typical secondary $PM_{2.5}$

Non-event : $NH_4SO_4 + NH_4NO_3 \sim 30\%$
24-hr $PM_{2.5} < 10\ \mu g/m^3$



BACKGROUND: TWO WINTER-TIME MODELLING STUDIES

Both to address winter-time $PM_{2.5}$ in the Capital Region through Photochemical Grid Model (PGM)

Why PGM?

- ✓ USEPA guidance (2014) requires use of photochemical models for secondary PM.
- ✓ Need to use full-chemistry models to simulate secondary PM formation as accurately as possible so using reduced-form chemistry models (e.g., CALPUFF) is not appropriate

Phase I (2014): To develop a CMAQ database that can be a reliable tool for analyzing $PM_{2.5}$ source contributions

- **CMAQ** is a regional PGM developed and maintained by the US EPA

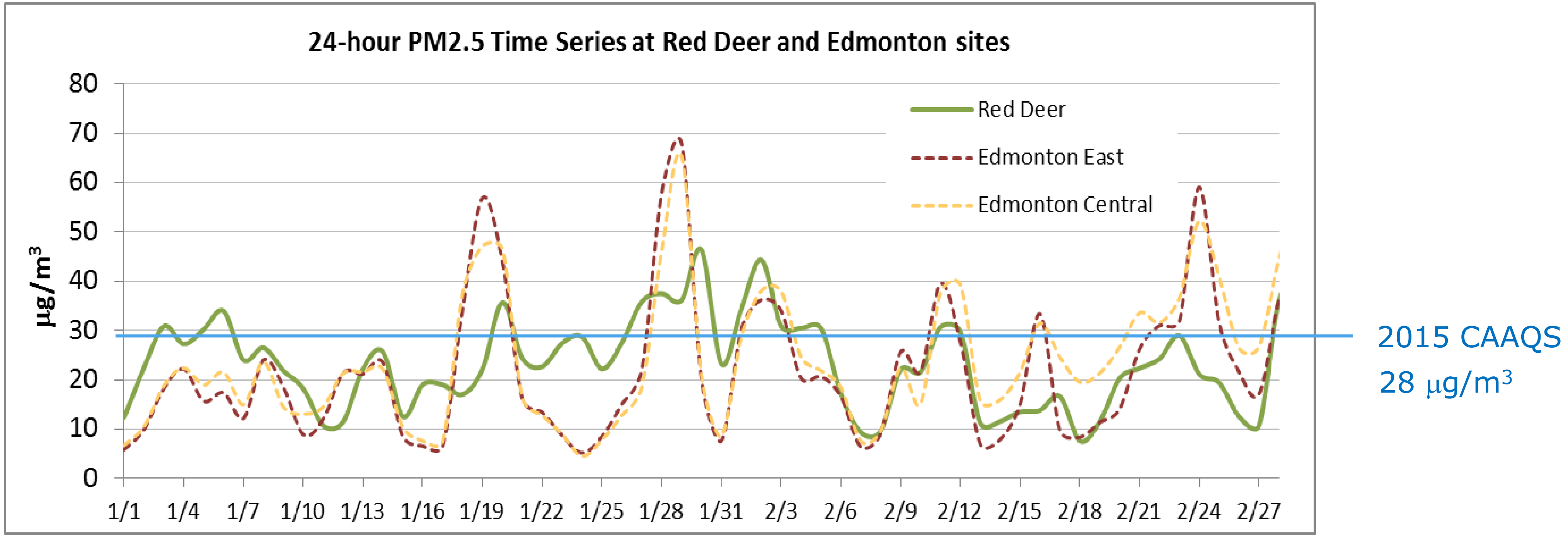
Phase II (2015): Improve Phase I modelling database

- Updated meteorology and emissions
- Multiple sensitivity tests -> model performance improved significantly

RAMBOLL

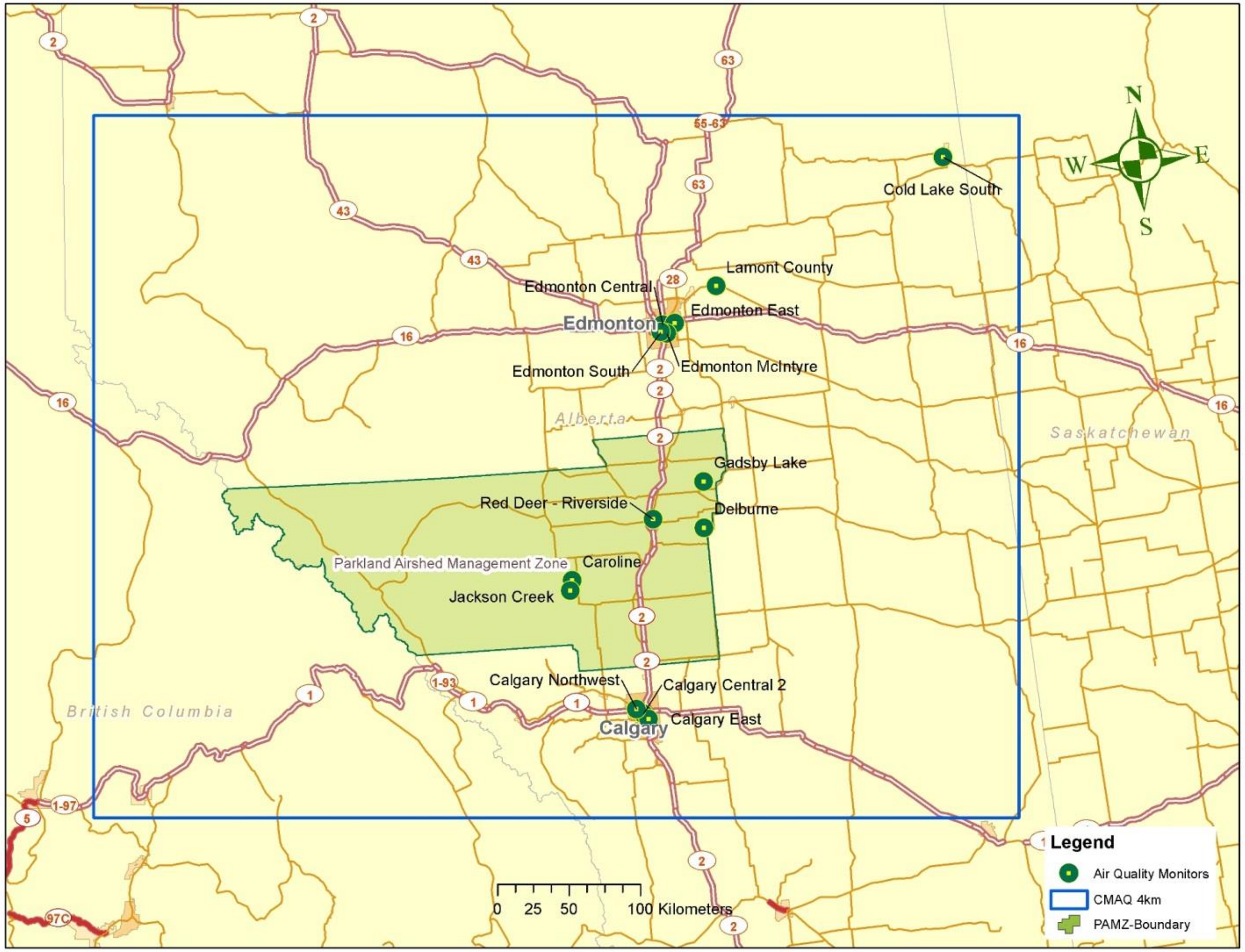
BACKGROUND: HIGH $PM_{2.5}$ OBSERVED IN RED DEER

Red Deer 24-hour $PM_{2.5}$ during Jan-Feb, 2010



BACKGROUND: STUDY GOALS

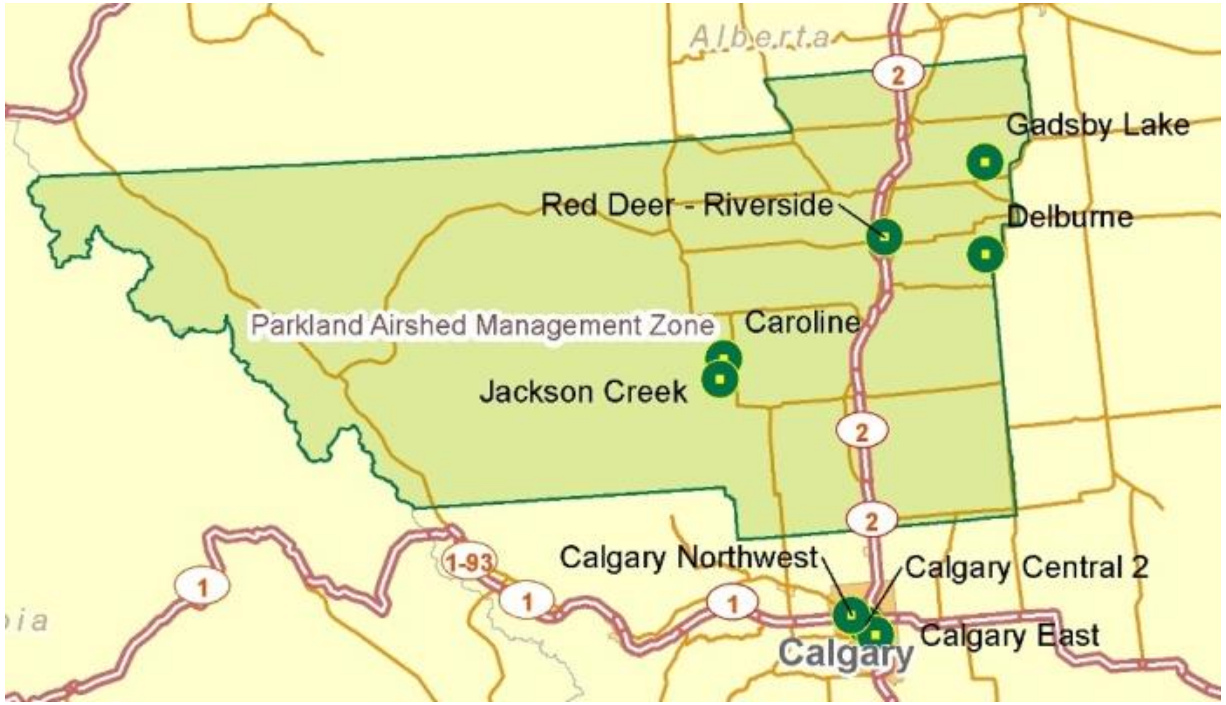
- Phase III to address high winter PM
- Adopt the existing CMAQ modelling database (Phase II) for Central Alberta
  - Refinement made for Red Deer areas
  - Tool for analyzing source contributions and control strategies



RAMBOLL

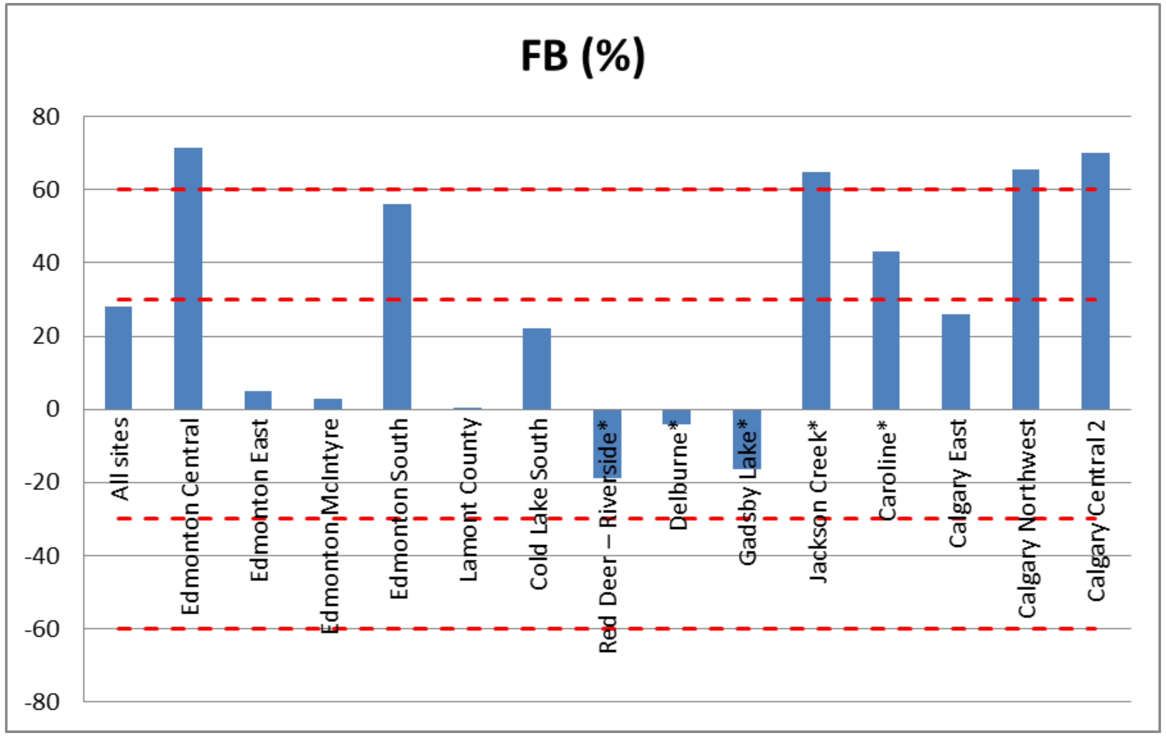
MODELLING METHODOLOGY

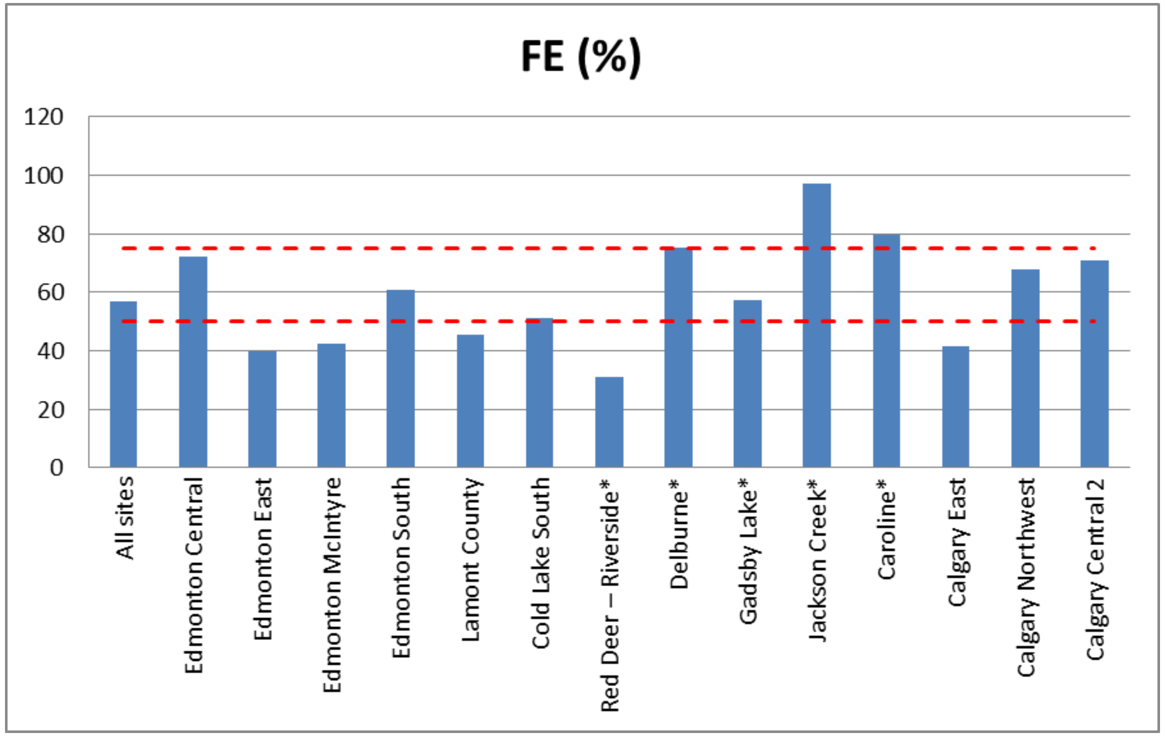
- Update model inputs specific to the Red Deer area
  - On-road mobile emission updates
  - Reallocation of residential wood combustion
- CMAQ setup (v 5.0.2)
  - 4 km covering central Alberta
- Modelling period: Jan-Feb, 2010
- Model performance evaluation
- Zero-out Simulations



RAMBOLL

PM2.5 PERFORMANCE SUMMARY





- Average across all sites, meet FB and FE performance criteria
- Best performed sites: Edmoton McIntyre, Edmonton East, Red Deer
- Worst performed sites: Caroline and Jackson Creek (low observed PM)

SOURCE ATTRIBITION: MODELLING

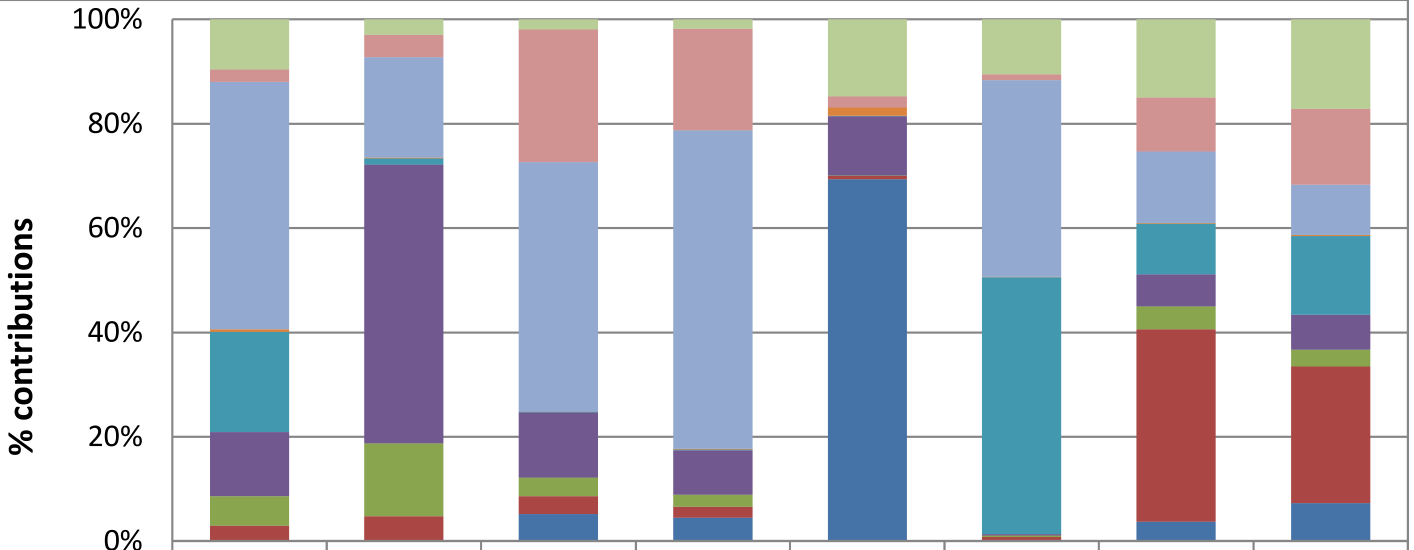
- Base Case setup with zero-out emissions to examine source contribution by sector
- Central Alberta zero-out simulations:

1. On-road mobile sources
2. Upstream oil and gas sources
3. Coal-fired electrical generating units
4. Other electrical generating units
5. Other stationary point sources
6. All Anthropogenic sources

- This approach can extend to quantify source contribution for each industrial source or sector (e.g., refineries, off-road mobile)

RAMBOLL

SOURCE ATTRIBUTION: EMISSIONS WITHIN MODELLING DOMAIN

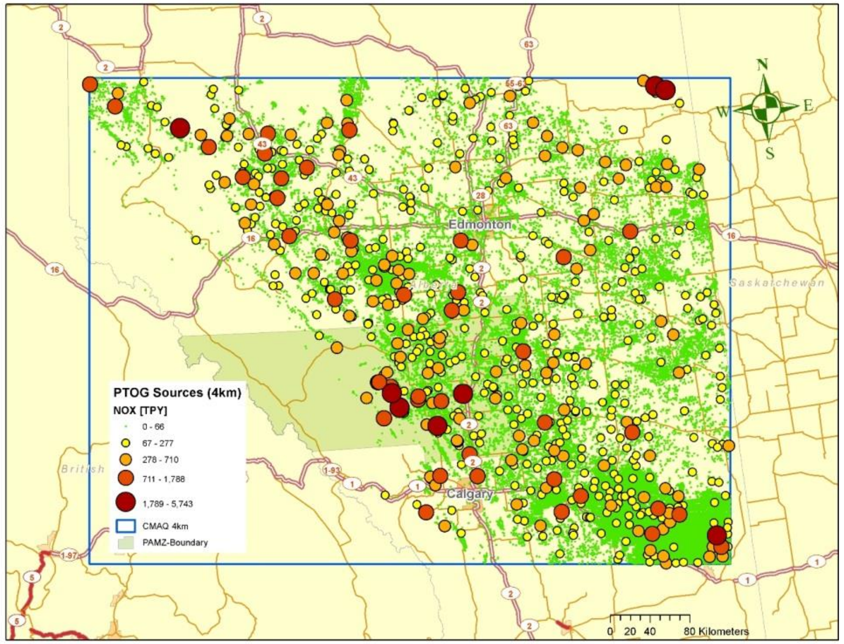


	NOx	CO	VOC	TOG	NH3	SO2	PM25	PM10
Point-others	115	77	14	22	10	79	9	14
Area-others	28	108	176	241	1	8	6	12
UOG	567	494	332	757	0	282	8	8
Non-Coal EGUs	6	5	0	2	1	0	0	0
Coal EGUs	230	30	1	2	0	368	6	13
On-road	146	1,369	87	105	8	2	4	6
Off-road	67	358	25	29	0	2	3	3
Comm & Res	36	122	23	26	0	6	21	22
Agriculture	-	1	36	56	47	-	2	6

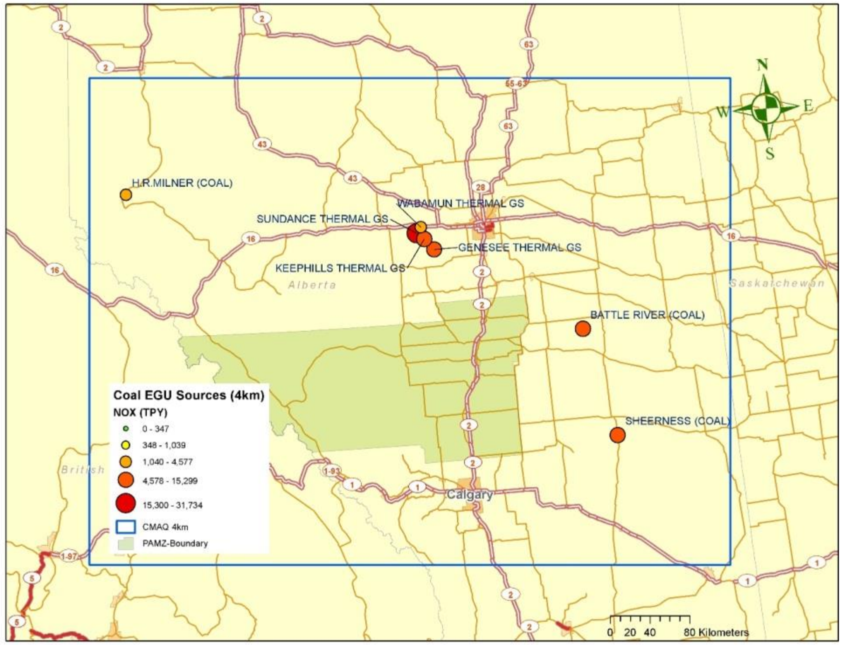
Emissions attribution alone cannot tell a complete story

Other factors

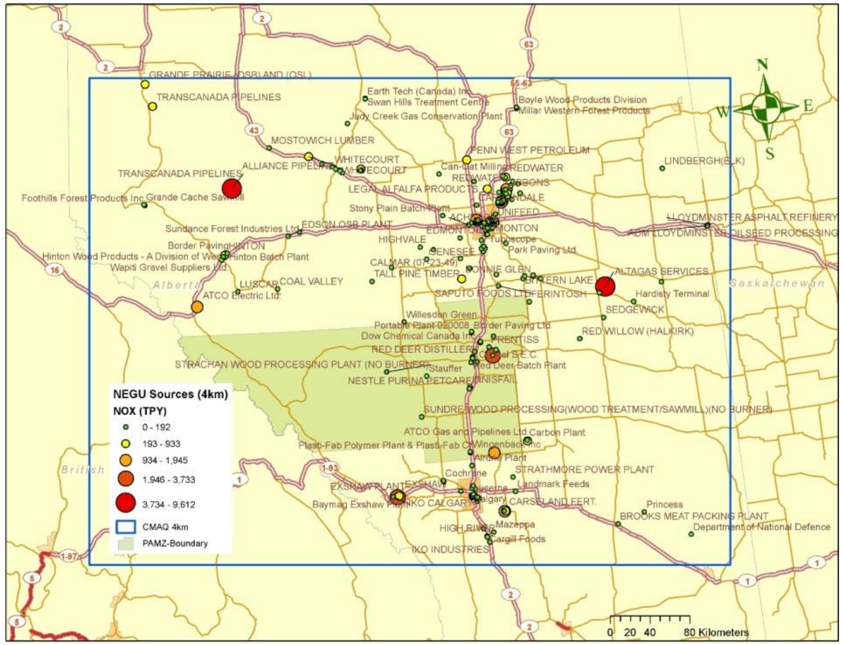
- Source location
- Stack parameters
- Composition of VOC emissions
- Meteorological conditions



UOG



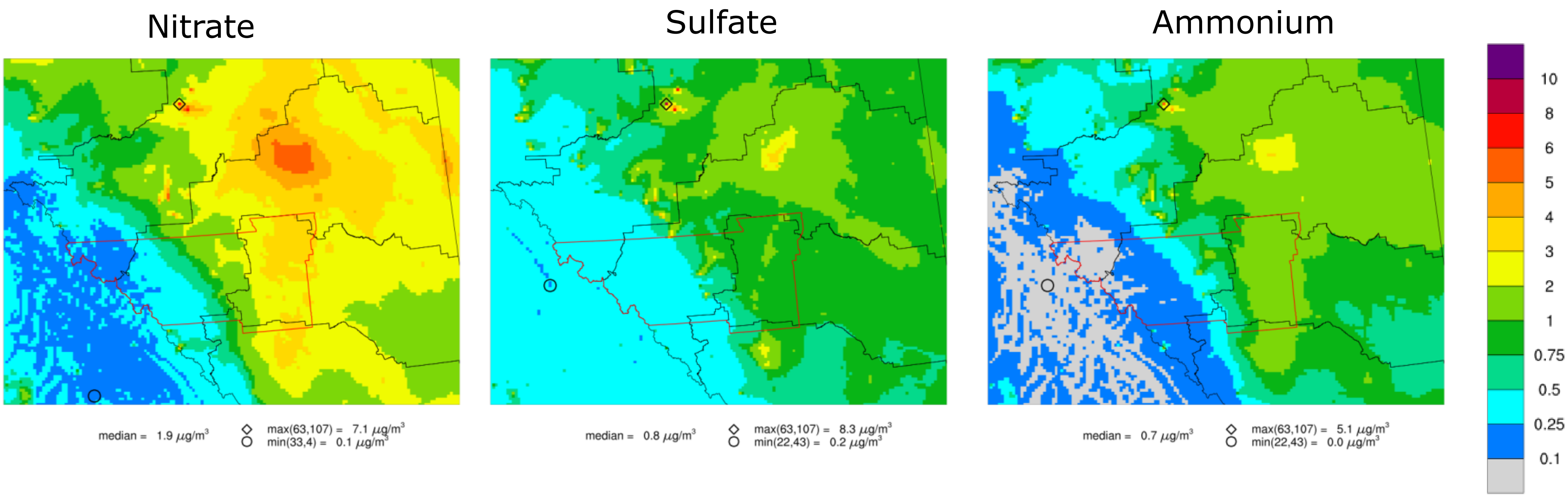
EGU



Other points

RAMBOLL

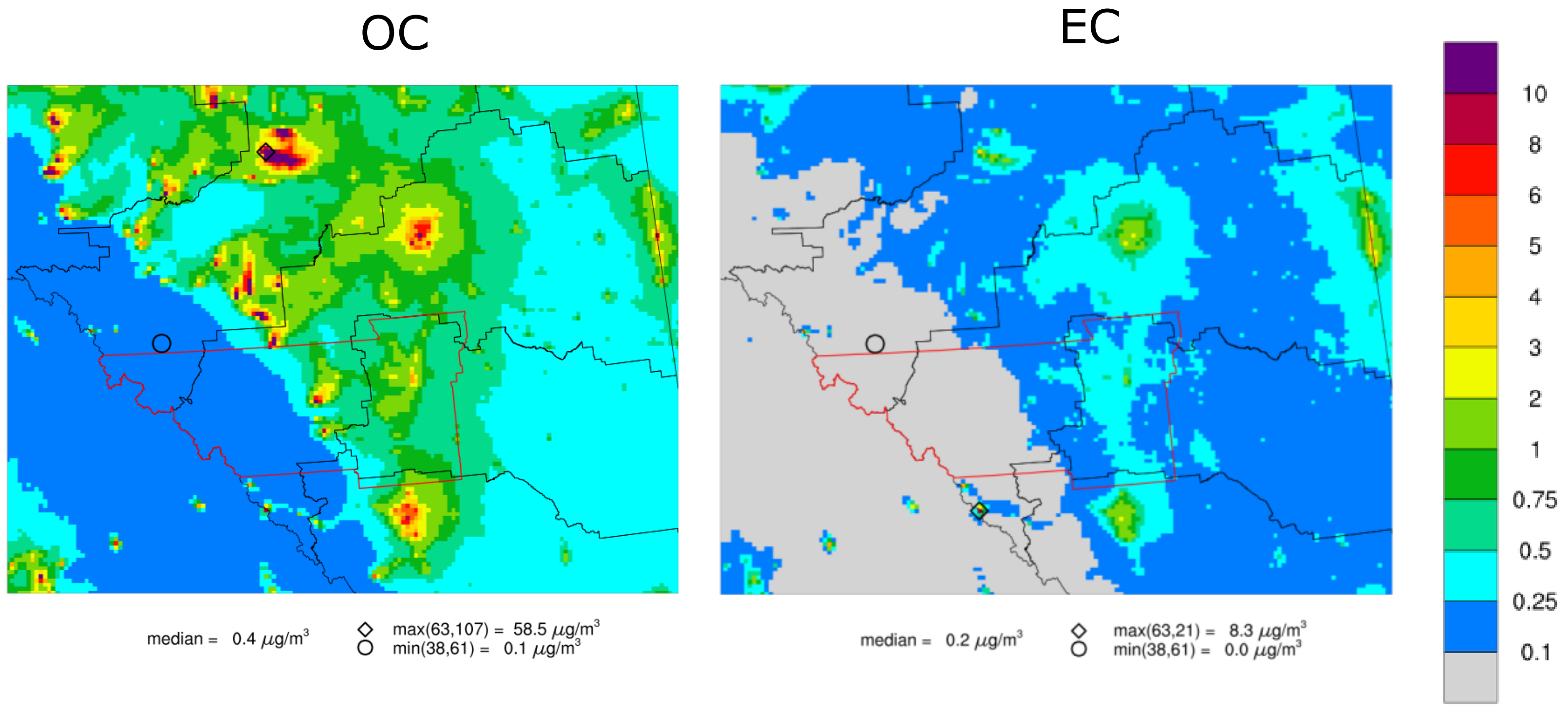
BASE CASE: JAN-FEB AVERAGE CONCENTRATIONS



Nitrate is a major constituent

- 5-6 $\mu g/m^3$ in Edmonton
- 4-5 $\mu g/m^3$ in Red Deer and Calgary

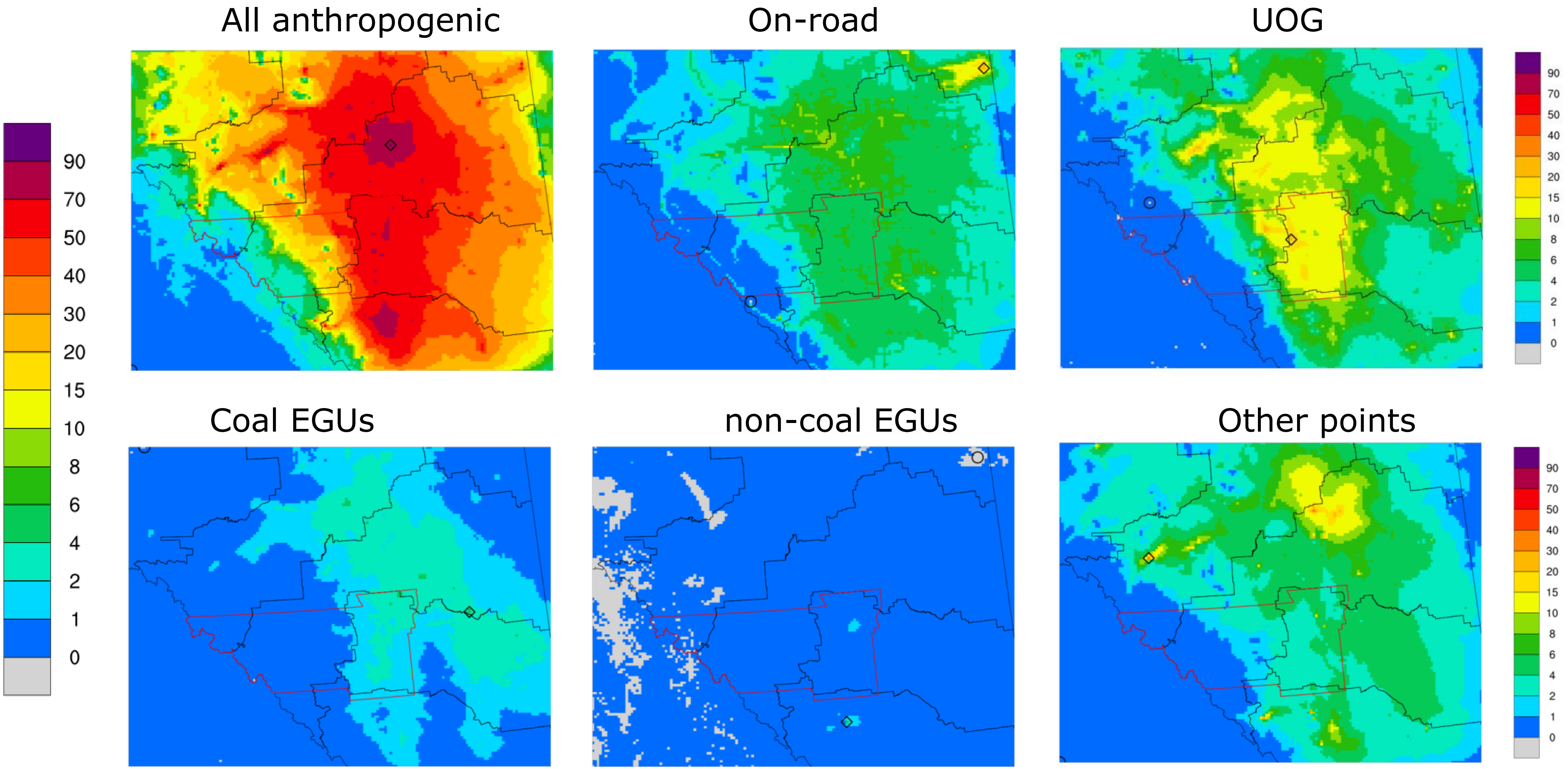
BASE CASE: JAN-FEB AVERAGE CONCENTRATIONS



- Commercial and residential emissions dominate $PM_{2.5}$ in urban areas
- Hot spots outside of urban areas are associated with fires (i.e., slash burn)

RAMBOLL

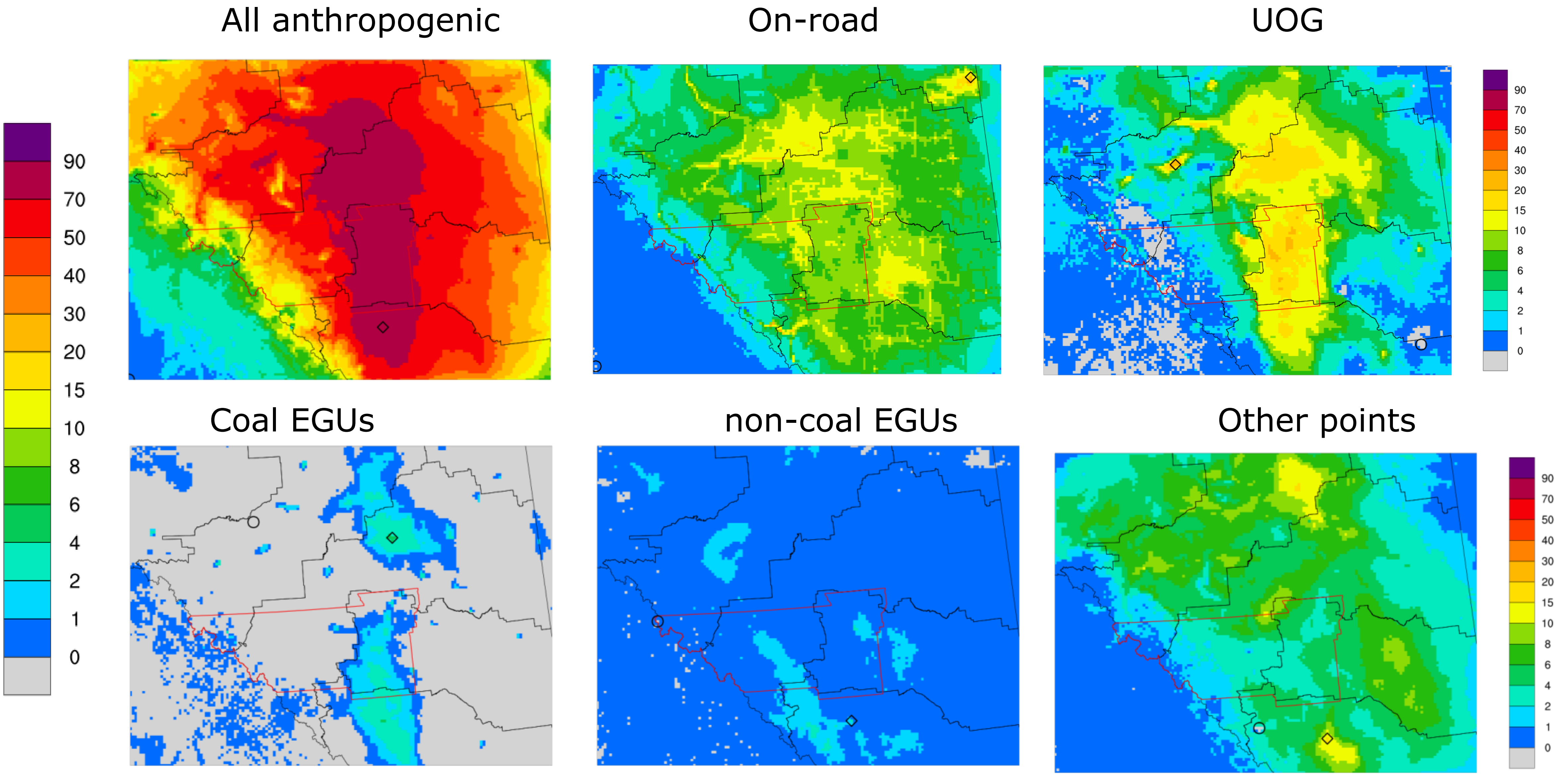
(%) CONTRIBUTION TO $PM_{2.5}$



RAMBOLL

- Largest contributions from UOG (10-15%; and spread out)

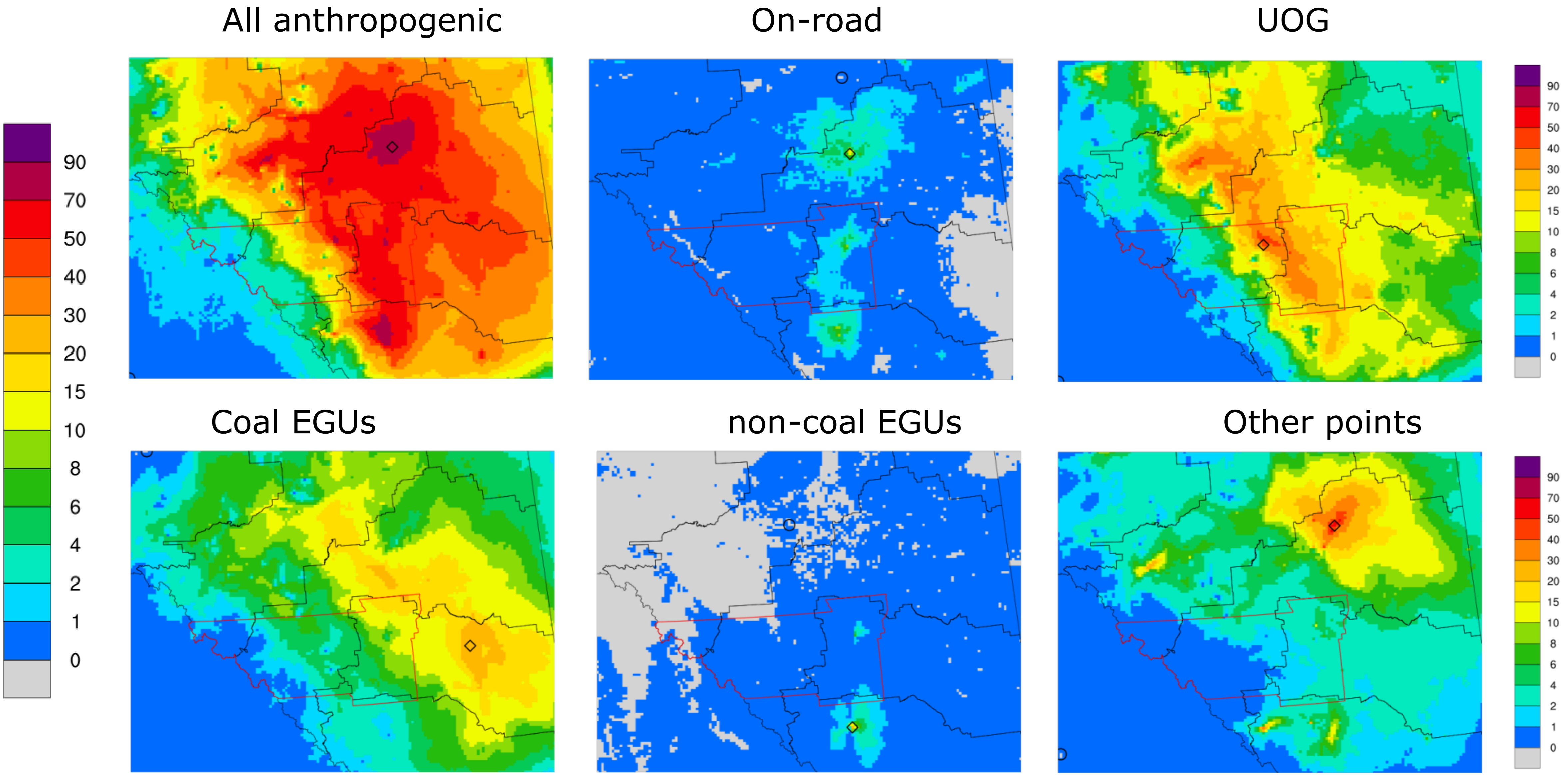
(%) CONTRIBUTION TO NITRATE



RAMBOLL

- Similar results seen for $PM_{2.5}$

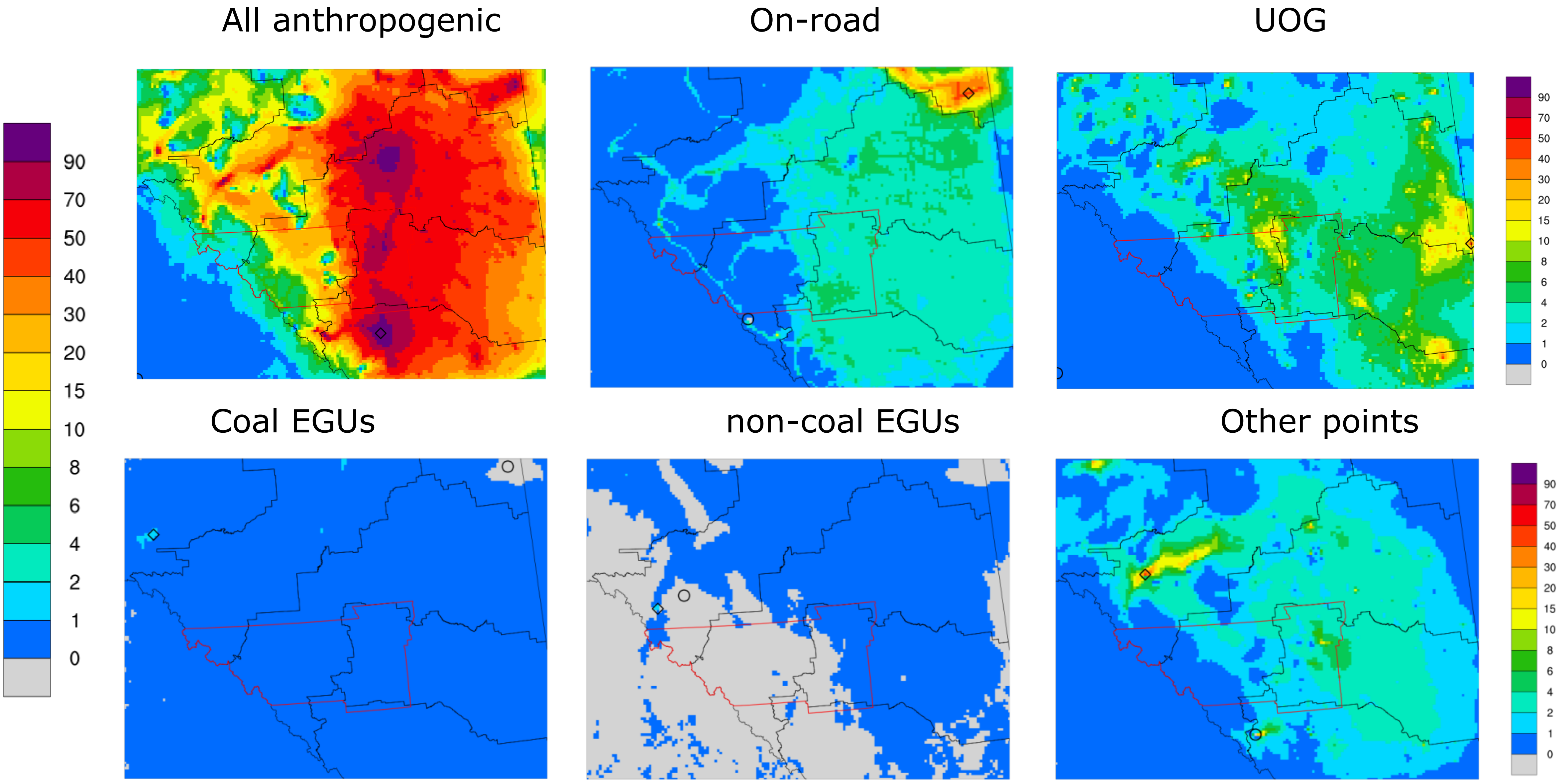
(%) CONTRIBUTION TO SULFATE



RAMBOLL

- UOG and coal EGUs dominate sulfate contributions

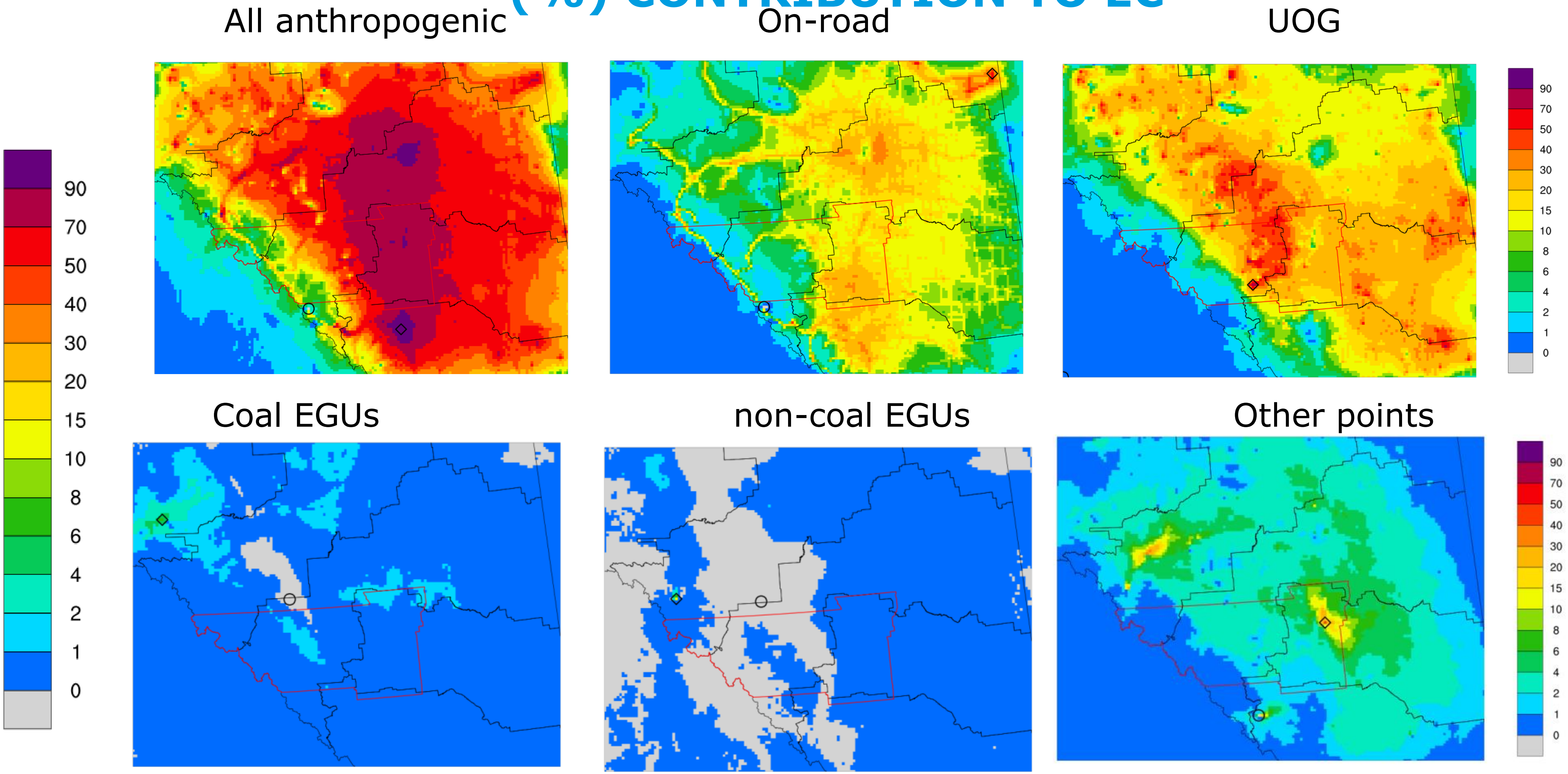
(%) CONTRIBUTION TO OC



RAMBOLL

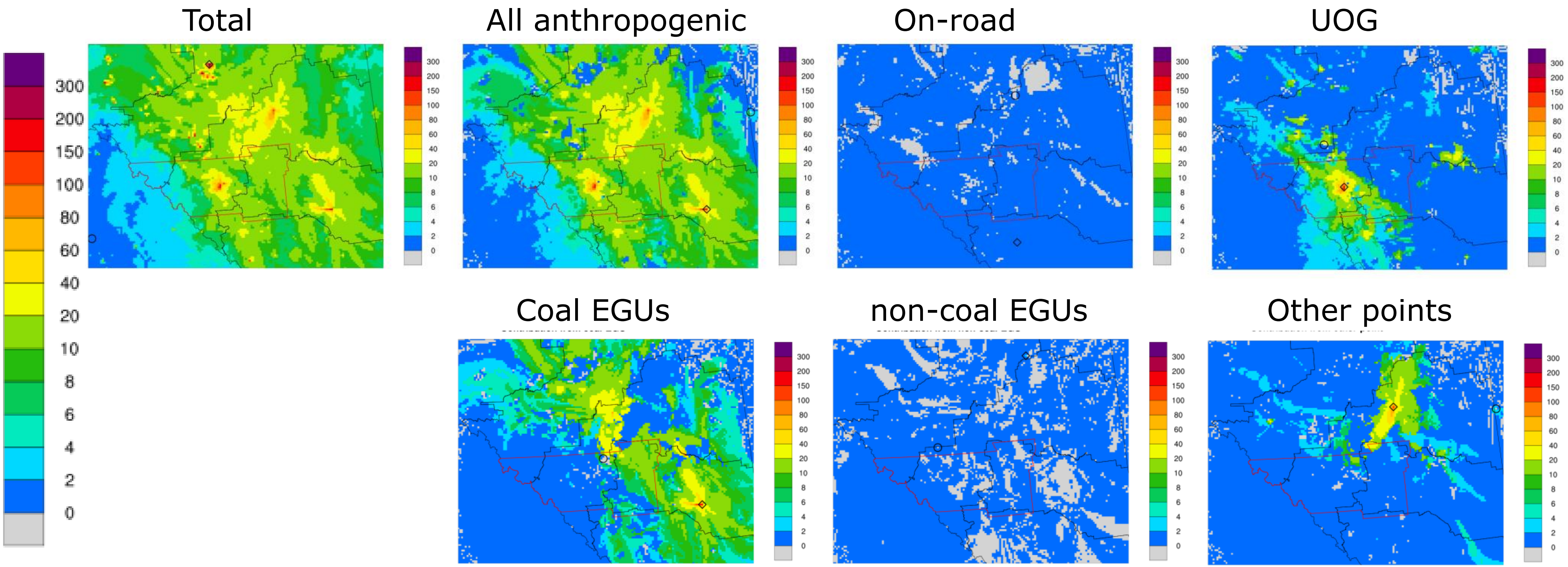
- Urban cores influenced by Comm&Res (individual sector contributes less than 10%)

(%) CONTRIBUTION TO EC



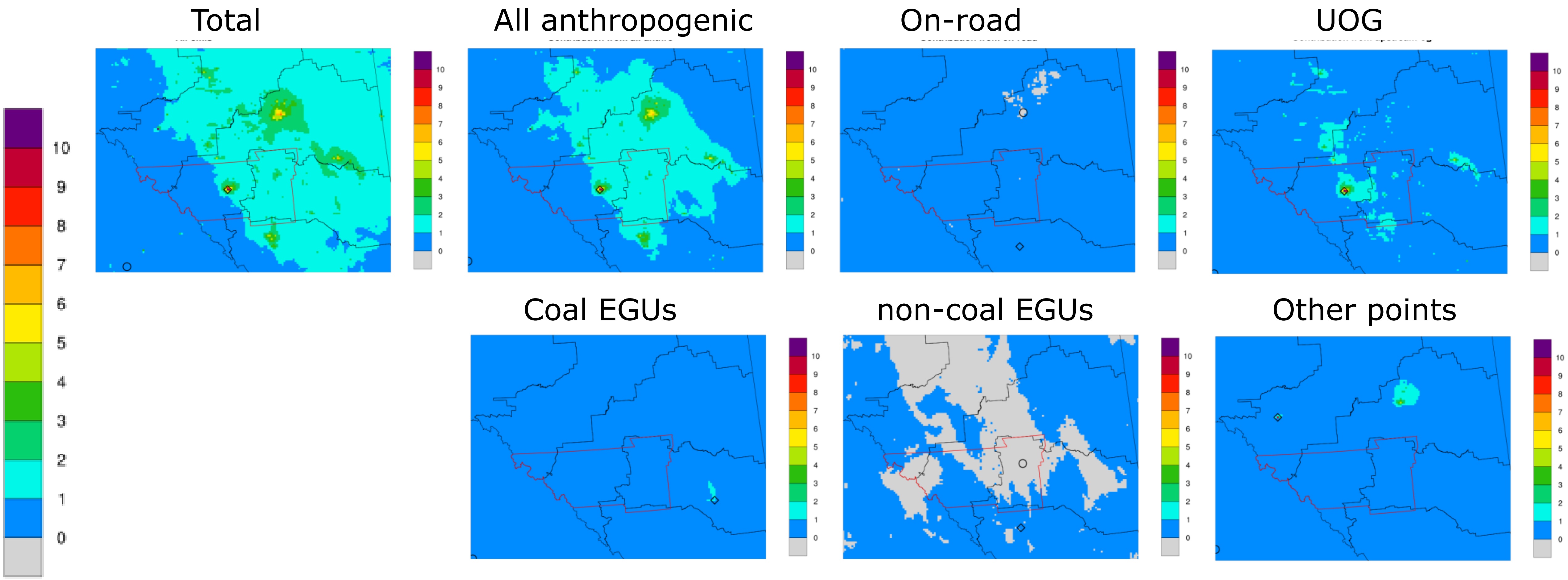
- Similar to OC results in urban cores
- Largest contributions from UOG and on-road

HIGHEST SO_2 (ABSOLUTE CONCENTRATIONS)



- Sharp gradients around large SO_2 sources: coal EGUs, UOG, other points

2-MONTH AVERAGE SO_2



- Coal EGU contributions are not as evident for the average metric

SUMMARY

- Source Contribution Analysis suggests most widespread $PM_{2.5}$ contributions from UOG
  - UOG max contribution is 23% in PAMZ; 5-15% in most areas
  - 70-90% contributions in urban cores are from local sources
  - 1-4% contributions from EGUs in most areas
  - > 20% contributions from other point sources but they are not as widespread
- Contributions to each PM component
  - Nitrate (most dominant): widespread contributions from on-road and UOG; off-road/residential sources also contribute
  - Sulfate: coal EGUs, UOG, and other point sources make up ~100%
  - OC/EC: some fire influences otherwise commercial and residential sources dominate
- SO_2 (emitting pollutants) contributions seen close to sources

RECOMMENDATIONS

- Closer look at UOG emission inventory
  - UOG emissions are most uncertain compared to other source sectors.
  - AEP 2017 project to update small-UOG emissions
- Refinement to other emission components with focus in Red Deer and vicinity
  - Review top emitters
  - Transport modelling (e.g., MOVES) specific to Red Deer/Calgary fleets
  - Verification with spectated observations will be critical
- Additional meteorology year or longer-term simulation
- Many possibilities to examine source contributions or policy-driven changes , e.g., off-road vs residential; conversion of coal-fired power plants to gas plants
- Multiple speciated PM monitors are helpful
  - Discrepancies of Dichot, sum of speciated components, TEOM

Thank You

Any questions?

This study was sponsored by Parkland Airshed Management Zone

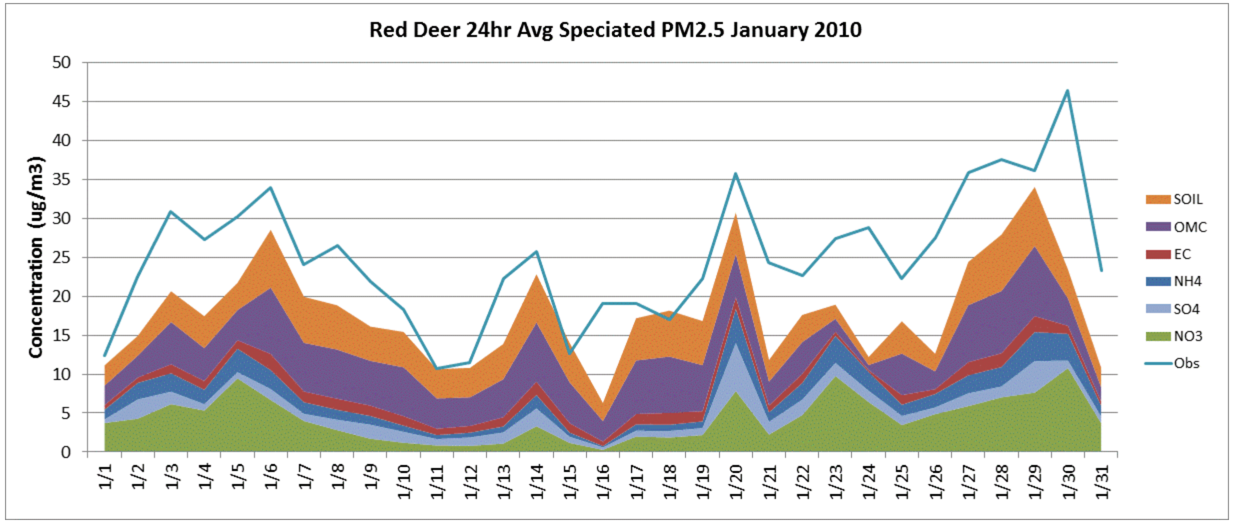
We thank Maxwell Mazur (AEP), David Lyder (AEP), and Kevin Warren (PAMZ) for their contributions

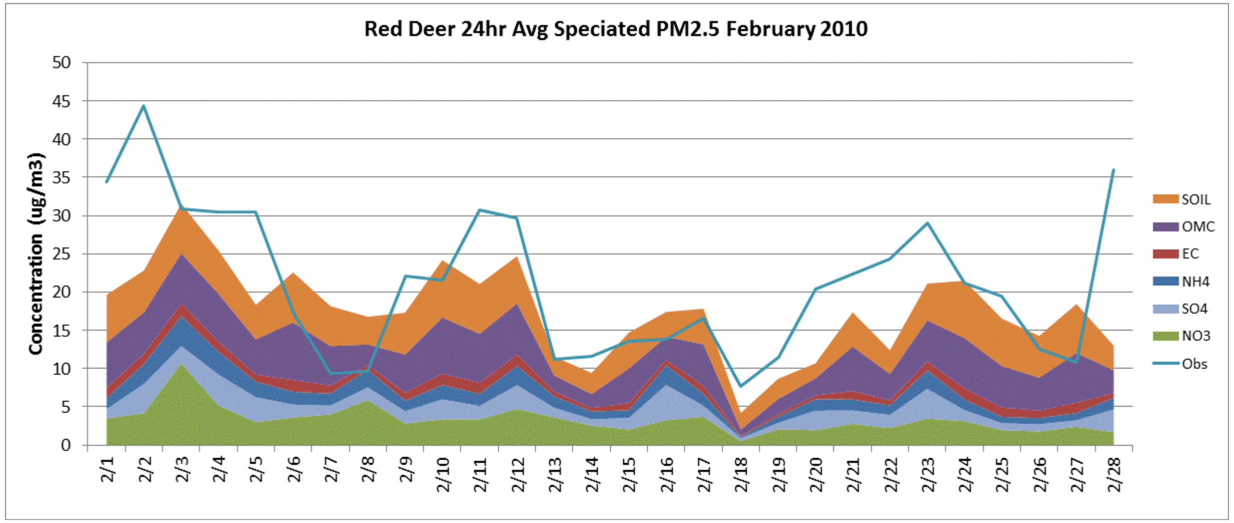
RAMBOLL

EXTRA SLIDES

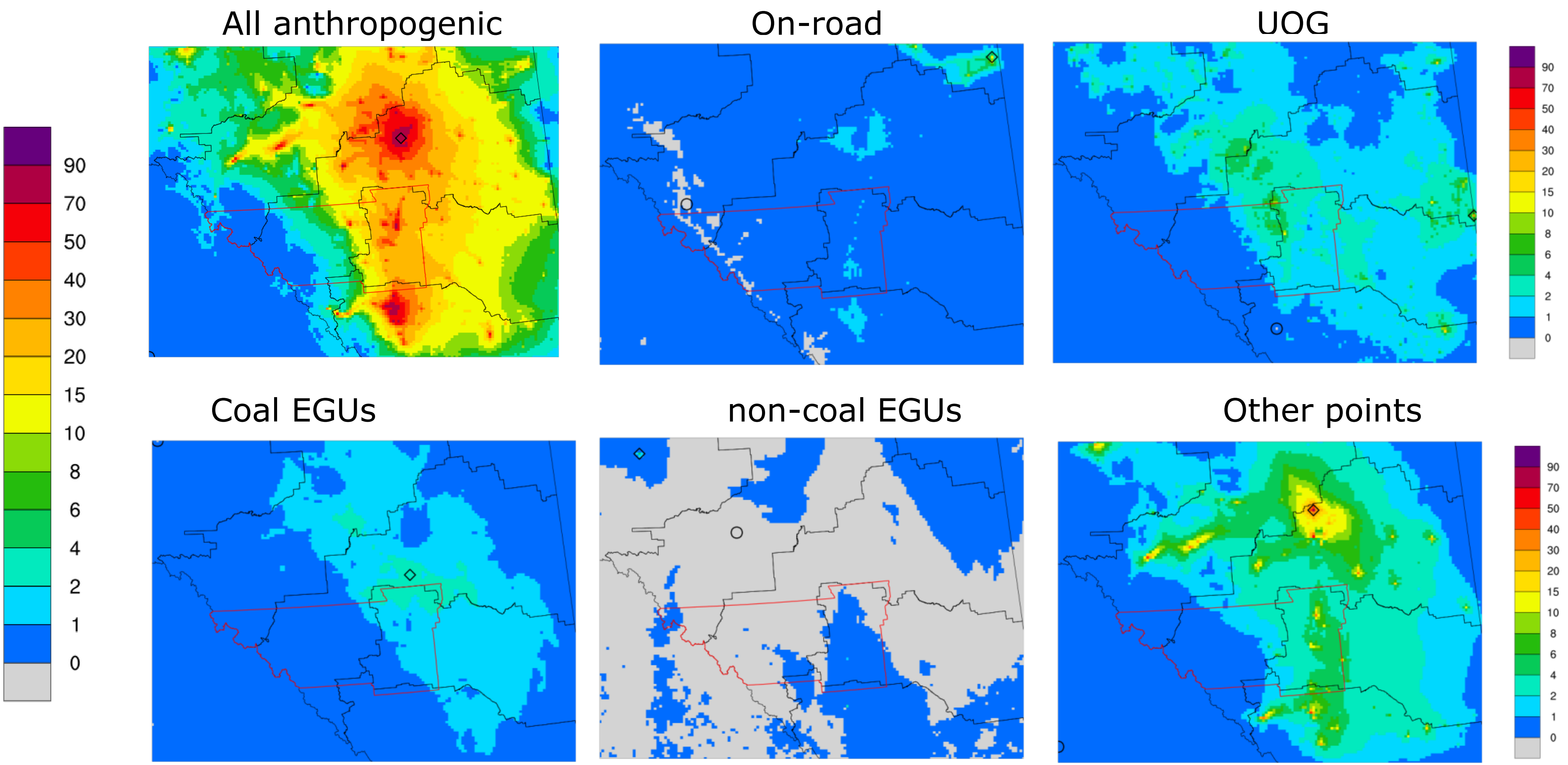
SUMMARY

- The 2010 winter modelling performs reasonably
  - Generally good WRF meteorological performance for the PAMZ sites
  - The model could reproduce observed $PM_{2.5}$ at Red Deer well with some under estimation bias (FB=-19%; PM Bias Performance Goal used in the past ≤±30%).
  - Model overestimation bias in Edmonton and Calgary sites, but such bias is not systematic
  - Need PM speciation measurements in Red Deer and vicinity to further fine-tune the modeling database



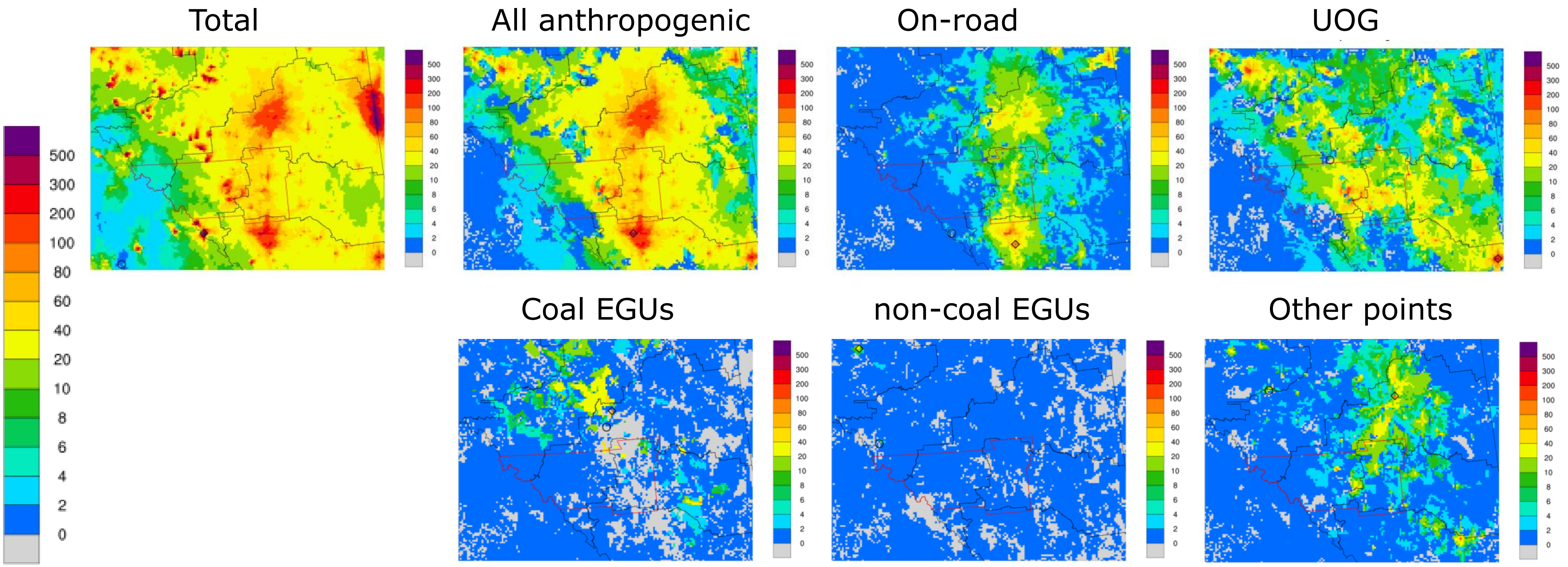


(%) CONTRIBUTION TO OTHER PM



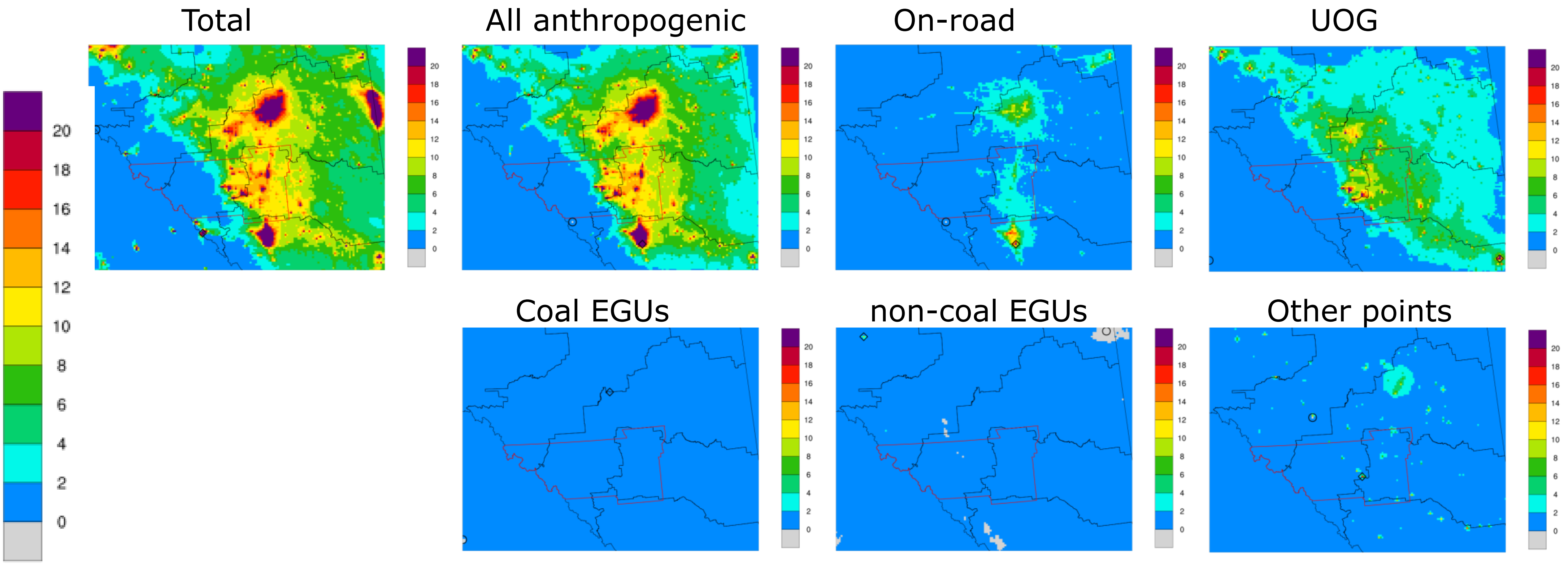
- Road (paved and unpaved) and construction dust likely dominates contributions in the urban areas

HIGHEST NO_X (ABSOLUTE CONCENTRATIONS)



- Sharp gradients around large NOx sources
- UOG in the western Alberta; On-road in urban cores; EGU in Capital Region

2-MONTH AVERAGE NO_X



- Similar to the highest NOx metric; smoother contours

RAMBOLL