

Canadian Anthropogenic Methane and Ethane Emissions: A Regional Air Quality Modeling Perspective

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INTRODUCTION AND MOTIVATION

- Methane (CH₄) is one of the most prevalent greenhouse gas (GHG) species. In 2016 the Canadian, U.S., and Mexican governments jointly committed to reduce CH₄ emissions from the natural gas and petroleum sector by 40-45% below 2012 levels by 2025
- Given that the natural gas and petroleum sector is also a large source of VOC emissions that affect air quality, the proposed CH₄ emissions reductions may also have co-benefits for air quality by reducing VOC emissions
- To study the co-benefits of VOC and GHG controls, Canadian anthropogenic CH₄ and ethane (C₂H₆) emissions, which are usually not classified as VOCs due to their low photochemical reactivity, are estimated using SMOKE from VOC emissions in the 2013 Canadian Criteria Air Contaminant (CAC) inventory used for AQ modelling
- The estimated CH₄ emissions from the CAC inventory are then compared with the CH₄ emissions in the Canadian national GHG inventory compiled for regulatory purposes
- This approach also allows the spatial and temporal distributions of CH₄ and C₂H₆ emissions to be described

METHODOLOGY

National CAC SCC-Specific VOC Emissions

Assign VOC Speciation Profile

Apply VOC-to-TOG Conversion Factors

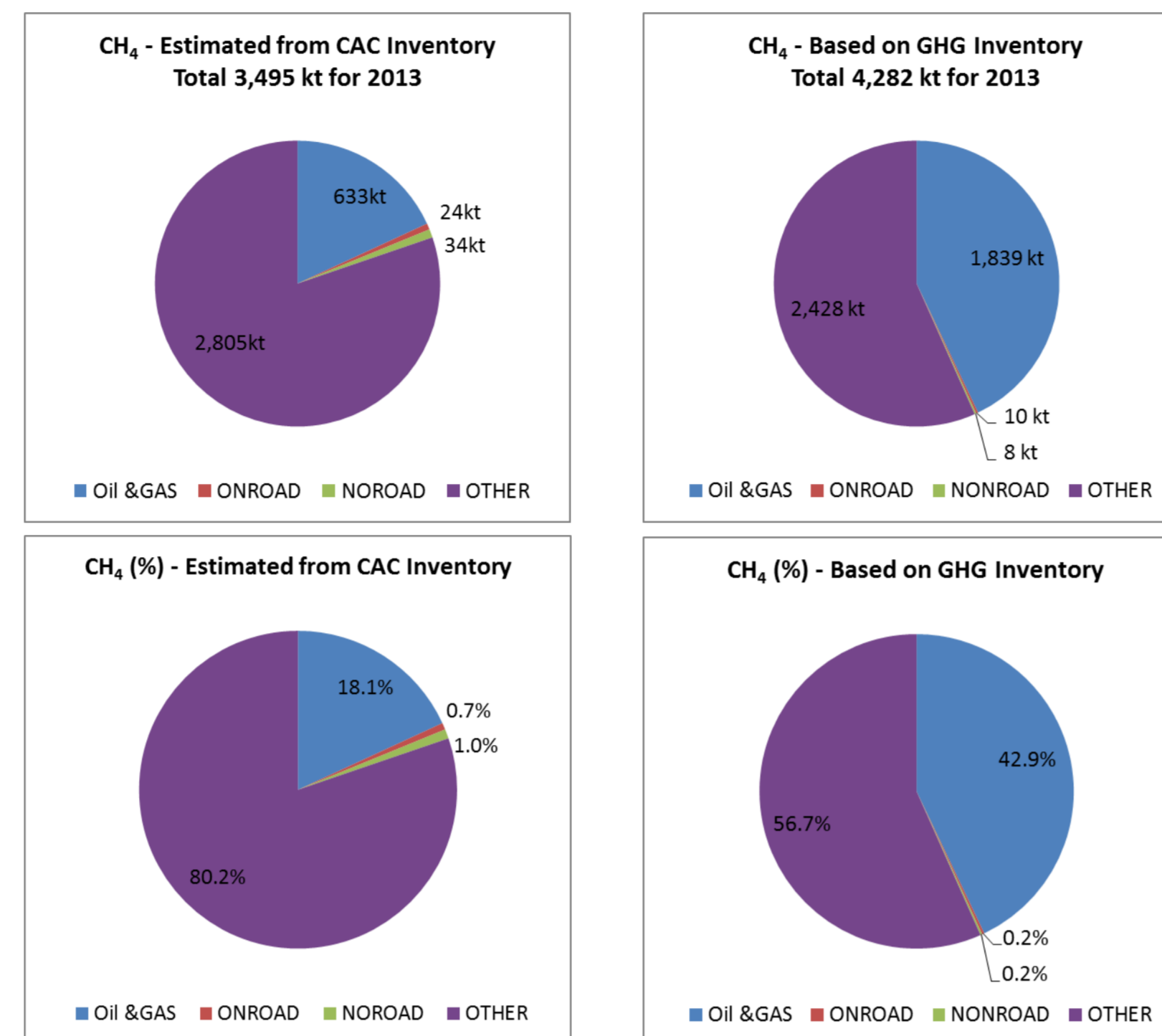
Total Organic Gas (TOG) Emissions

Apply Weight Percentages of CH₄ and C₂H₆

Apply Spatial Surrogates & Temporal Profiles

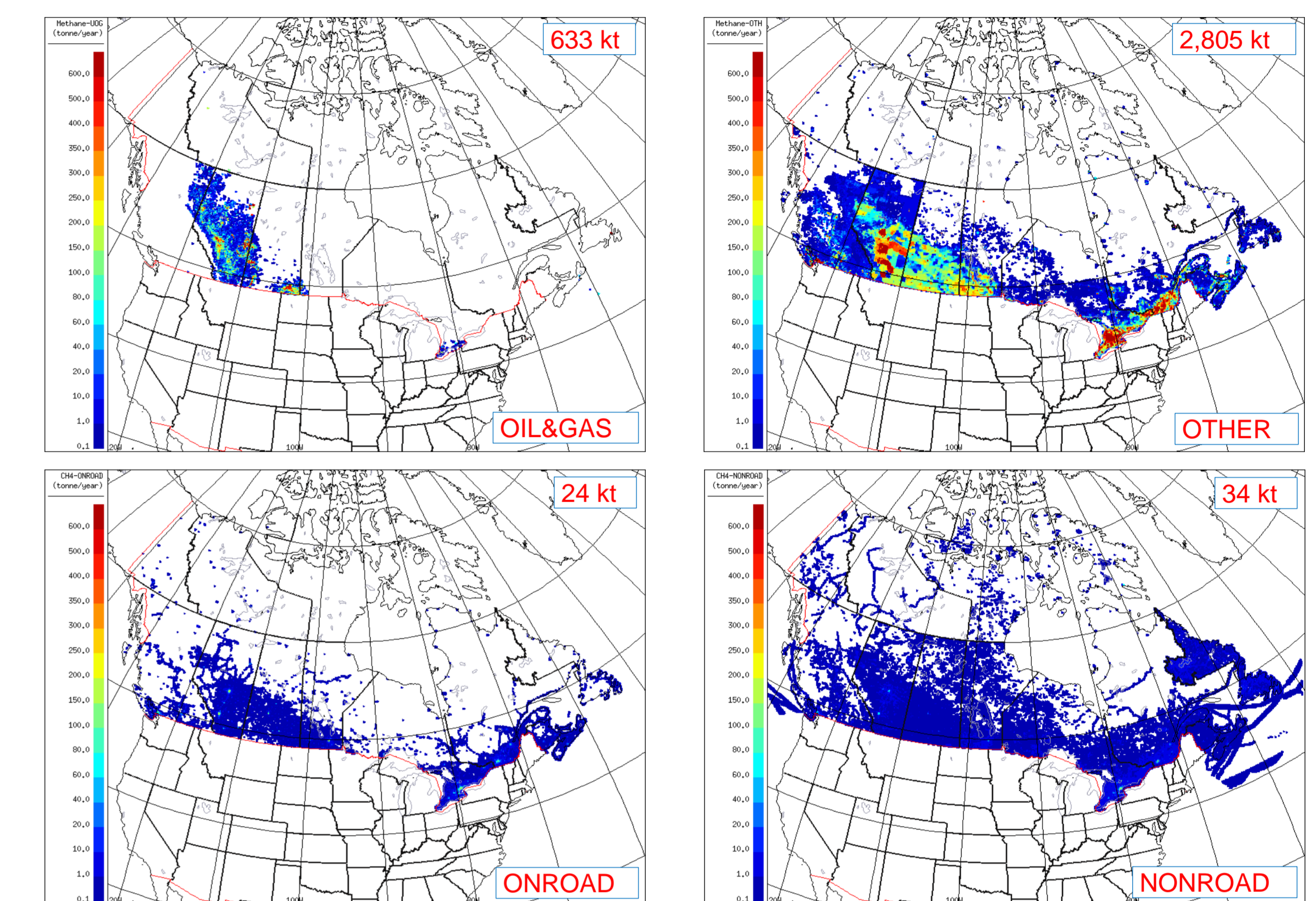
Hourly Methane and Ethane Emissions Over a National 10-km Domain

CAC-Estimated vs. GHG-Inventory CH₄ Emissions

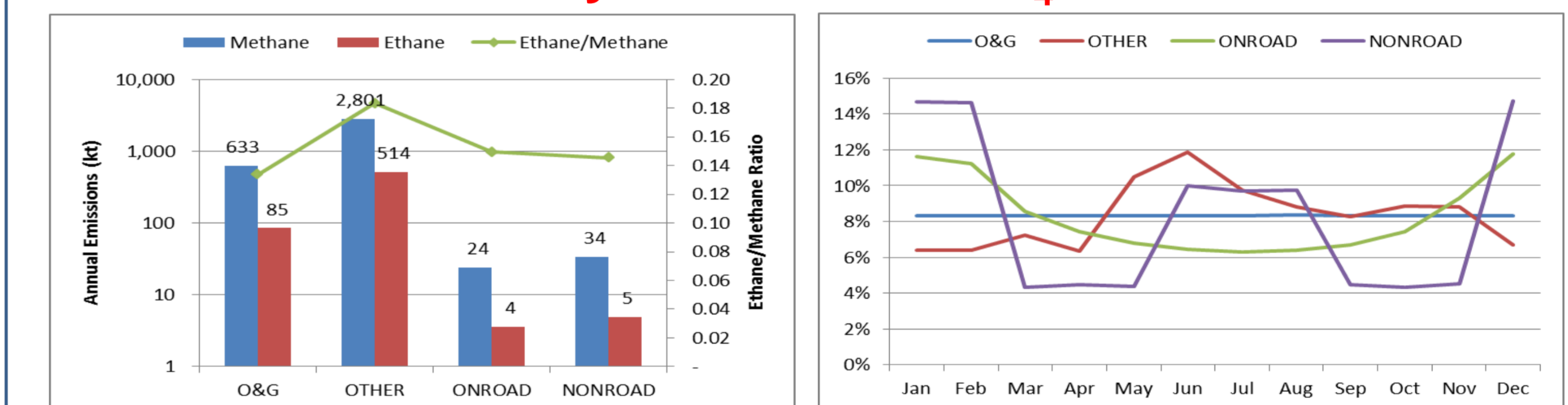


- Total of CAC-estimated CH₄ emissions is 18% smaller than GHG inventory total
- CAC-estimated CH₄ emissions from gas and petroleum sector are 1/3 of those in the GHG inventory
- CH₄ emissions from onroad and nonroad sectors are small, less than 1% of national total CH₄ emissions
- CAC-estimated CH₄ emissions from all other sources (OTHER) are slightly larger than those in the GHG inventory

Annual Spatial Distribution of CAC-Estimated CH₄ Emissions for 4 Primary Source Sectors



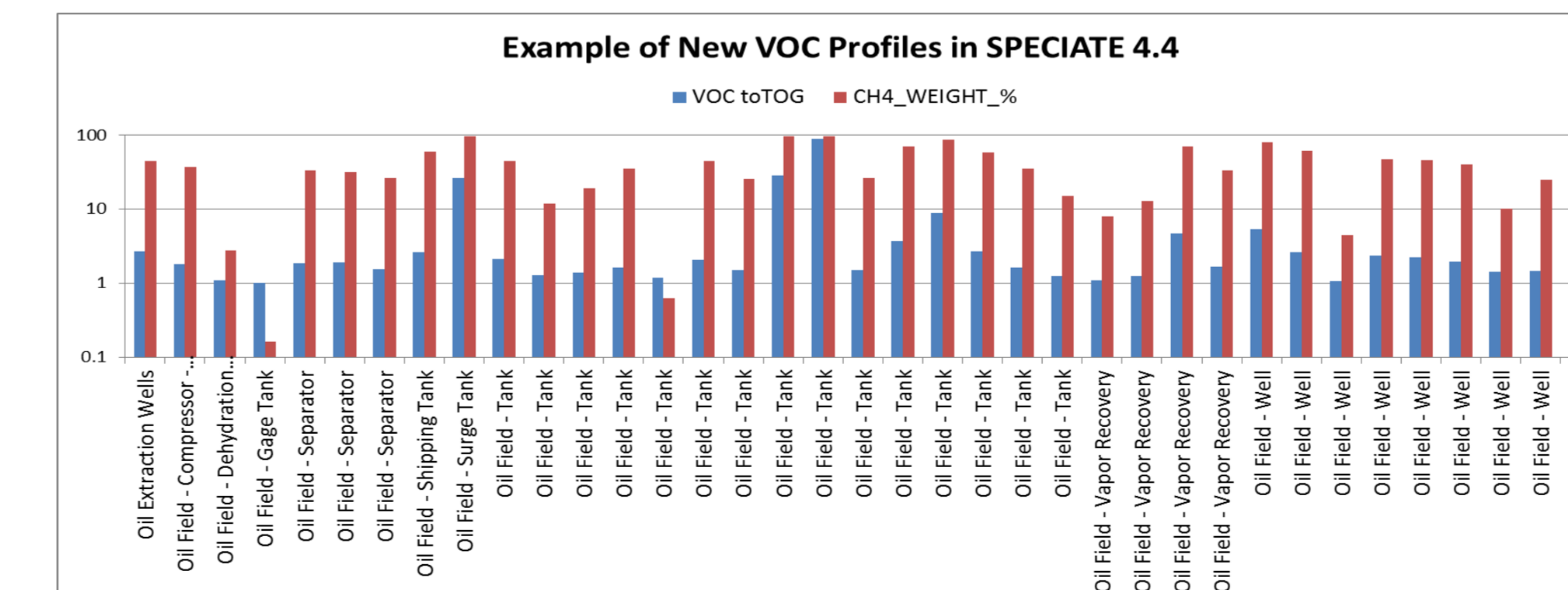
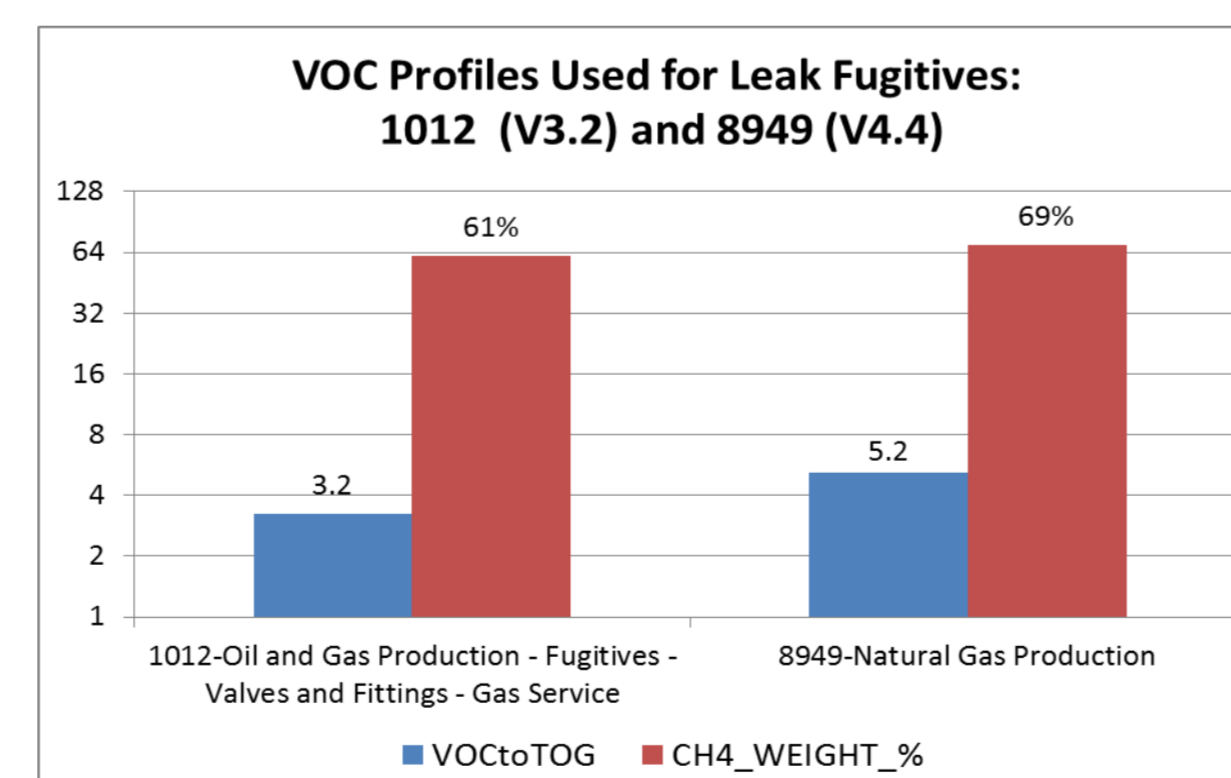
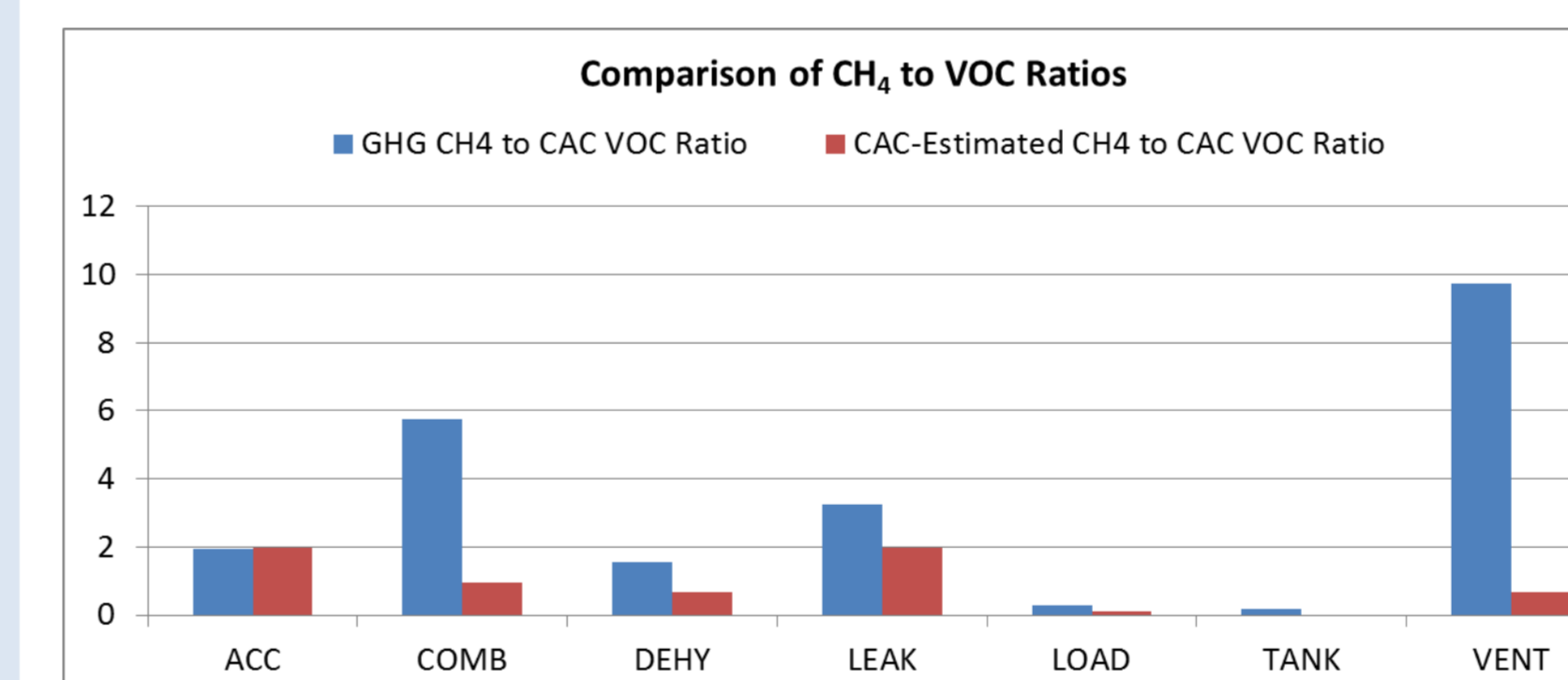
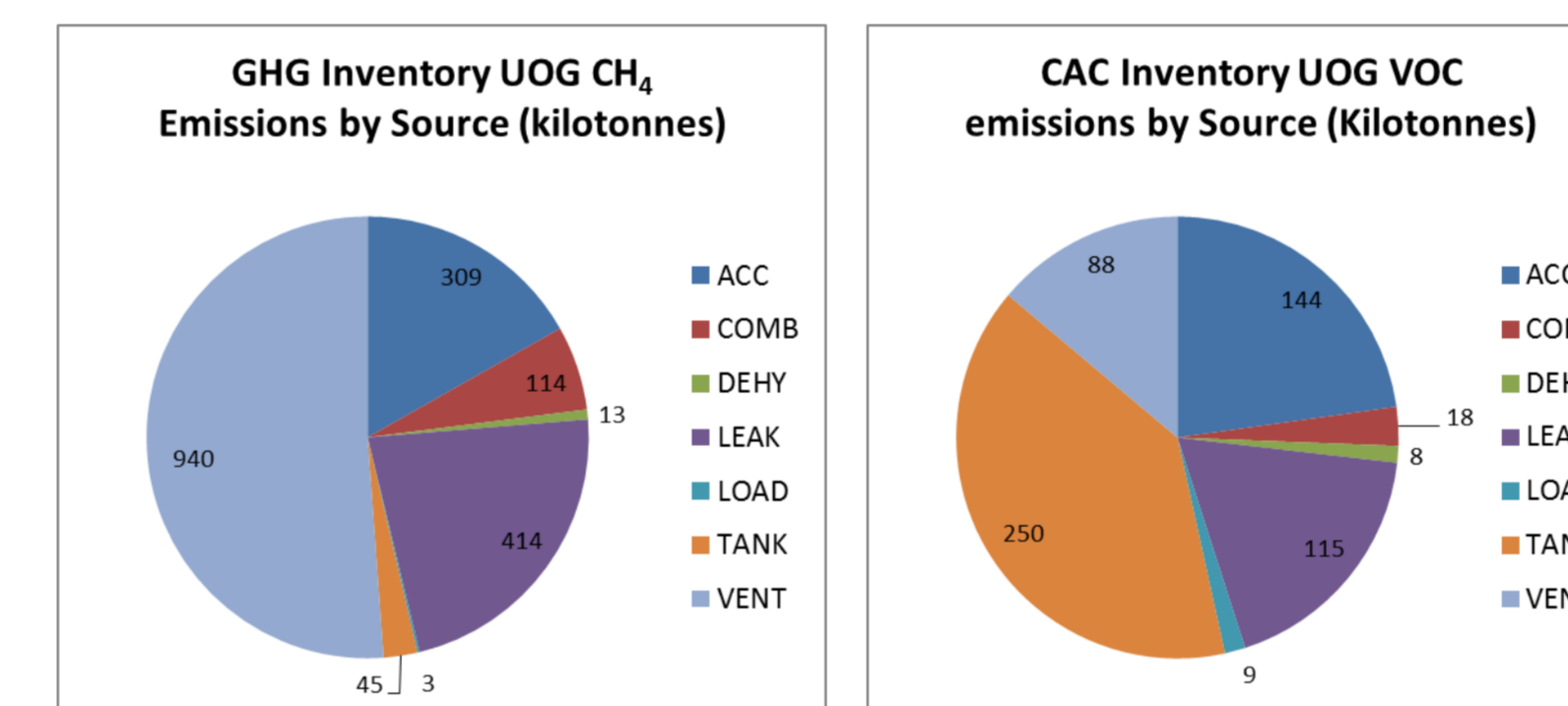
Annual CH₄ and C₂H₆ Emissions, CH₄-to-C₂H₆ Ratios, and Monthly Variation of CH₄ Emissions



- CH₄ emissions from the Gas and Petroleum industry are mainly from the province of Alberta, in agreement with GHG inventory
- Alberta also emits large amounts of CH₄ from other area sources, mostly from the agriculture sector. Significant amounts of CH₄ were also emitted from agricultural areas in the provinces of Saskatchewan, Manitoba, Ontario, and Quebec, also in agreement with the national GHG inventory
- Total C₂H₆ emissions are about 15% of CH₄ emissions, but this fraction varies between source types
- The Gas and Petroleum industry emits CH₄ almost constantly throughout the year, whereas CH₄ emissions from other sectors have strong seasonal variations

Analysis of VOC and CH₄ Emissions and VOC Profiles for the Upstream Oil and Gas (UOG) Sector

- UOG sector accounts for 97.5% of total CH₄ emissions from the Canadian natural gas and petroleum sector
- GHG CH₄ and CAC VOC emissions from the UOG sector were derived from the same source of data, allowing a straightforward comparison between CAC-estimated CH₄ emissions and those in the GHG inventory
- Ratios of GHG CH₄ emissions to the CAC VOC emissions vary greatly by source type from 0.2 (TANK) to 9.7 (VENT) (see plot to right)
- Ratios of CAC estimated CH₄-to-VOC emissions also vary greatly by source type. Several are very different from the GHG CH₄-to-VOC ratios, indicating that the VOC profiles applied to these sources are not appropriate



- SPECIATE 3.2 VOC speciation profiles created decades ago were used for this study
- The U.S. EPA has updated some oil-and-gas-related VOC profiles in their 2011v2 modeling platform. For example, profile 1012 for equipment leak fugitives from natural gas production was replaced by 8 region-specific and one generic (8949) profiles (see left-hand plot above for comparison of profiles 1012 and 8949)
- When profile 8949 is used for LEAK emissions, the CAC-estimated CH₄-to-VOC ratio increases from 2.0 to 3.6, much closer to the GHG CH₄-to-VOC ratio of 3.3
- Newer oil-and-gas-related profiles are available in the SPECIATE 4.4 database, but their VOC-to-TOG conversion factors can vary greatly for the same source type (see right-hand plot above), indicating uncertainty in the VOC profiles used for the gas and petroleum sector

CONCLUSIONS

- The emissions-processing methodology that was applied here for the first time to estimate CH₄ and C₂H₆ emissions from a non-GHG inventory was quite successful
- CAC-inventory-based estimates of CH₄ emissions for the UOG sector are one-third of those from the GHG inventory, indicating a need to update some VOC speciation profiles and/or develop some region-specific profiles for Canada
- Estimated CH₄ emissions from other sectors agree reasonably well with the Canadian GHG inventory
- The detailed plots above of the spatial and monthly distributions of Canadian CH₄ emissions is new
- Total C₂H₆ emissions are about 15% of CH₄ emissions