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Canada

Measurements of Methane Emissions from Canadian Bakken Shale Oil Fields and Oil Sands Surface Mining Facilities

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Acknowledgements

- Senior researchers who have led this work
  - Dr. Shao-Meng Li – ECCC
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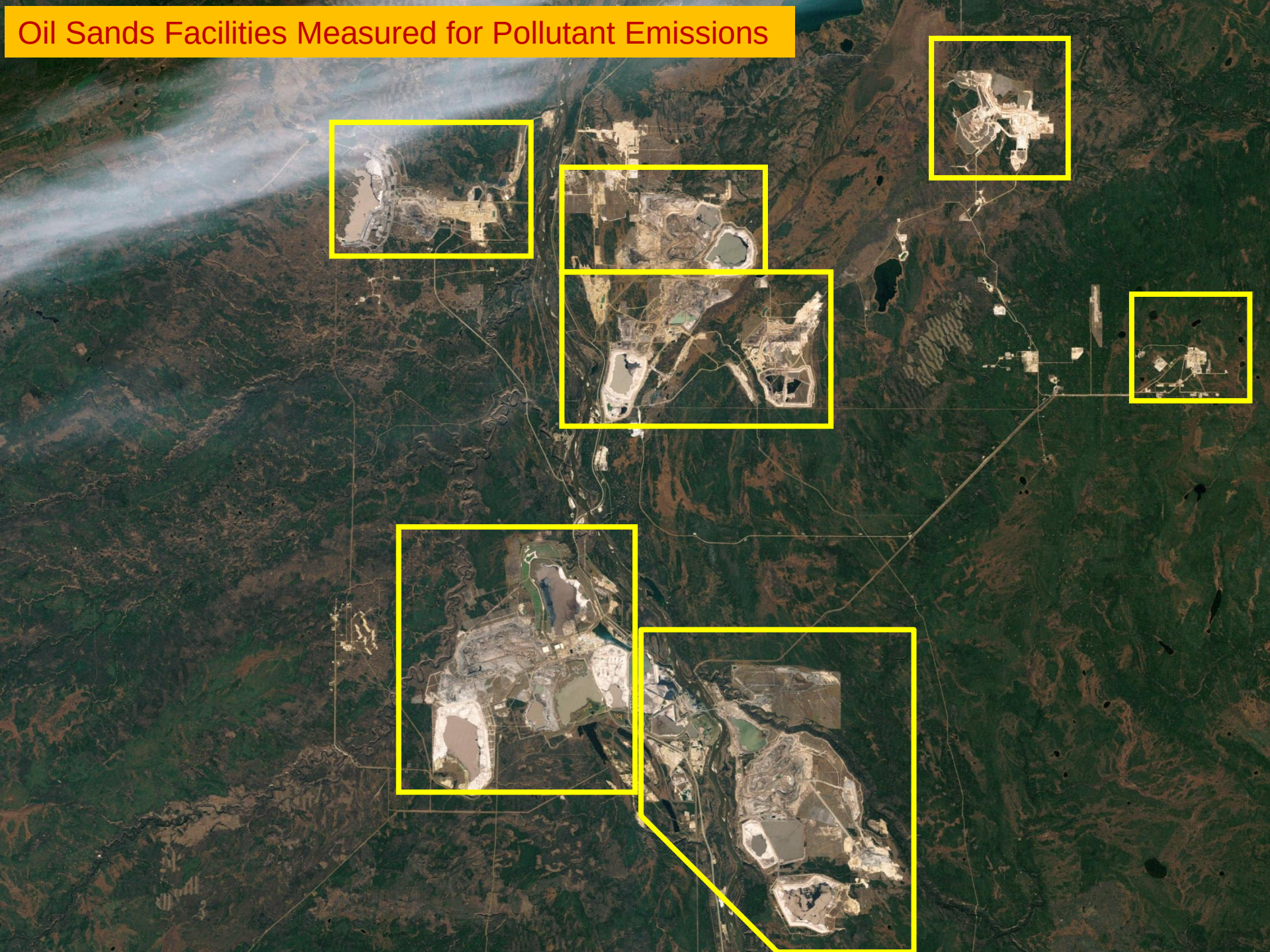
  - Dr. John Liggio – ECCC
  - Professor Robert McLaren – York University
  - Dr. S. Baray – York University
  - Katherine Hayden – ECCC
  - Doug Worthy - ECCC
  - Dr. Mengistu Wolde – National Research Council of Canada

Aim

- To demonstrate the utility of two top-down emissions estimation methods and provide examples of their application to oil sands surface mining and Canadian Bakken shale oil field facilities.


Oil Sands Facilities Measured for Pollutant Emissions

Atmos. Meas. Tech., 8, 3745–3765, 2015
www.atmos-meas-tech.net/8/3745/2015/
doi:10.5194/amt-8-3745-2015

Atmospheric Measurement Techniques
Open Access

Determining air pollutant emission rates based on mass balance using airborne measurement data over the Alberta oil sands operations

Gordon et al. (2015)

Top-down Emission Rate Retrieval Algorithm (TERRA)

$$E = E_L + E_{fL} + E_T + E_{fT} + E_d + Ec - E_m$$

Emission Rate

Lateral Transport

Lateral Turb. Flux

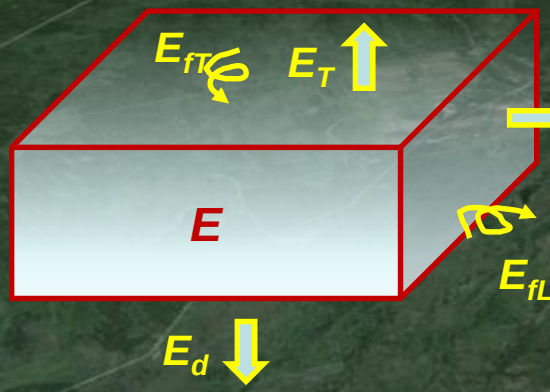
Vertical Transport

Vertical Turb. Flux

Deposition to Surface

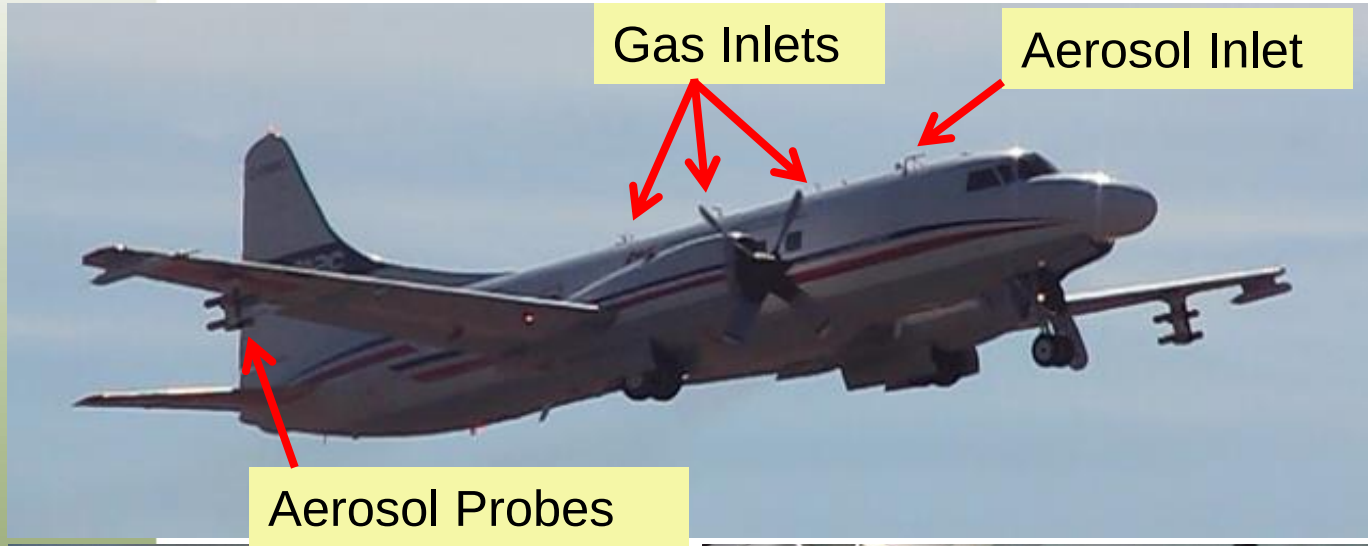
Chemistry

Change in mass



Wind

Aircraft and instruments - 2013 study



Gases, 1-5 sec

- CRDS: CO, CO_2, H_2S, CH_4
- PTR-ToF-MS: VOCs
- Canisters: VOCs
- TECO: NO/NO_2/NOy/O_3/SO_2
- QCL: NH_3, HCHO
- CIMS: Acids

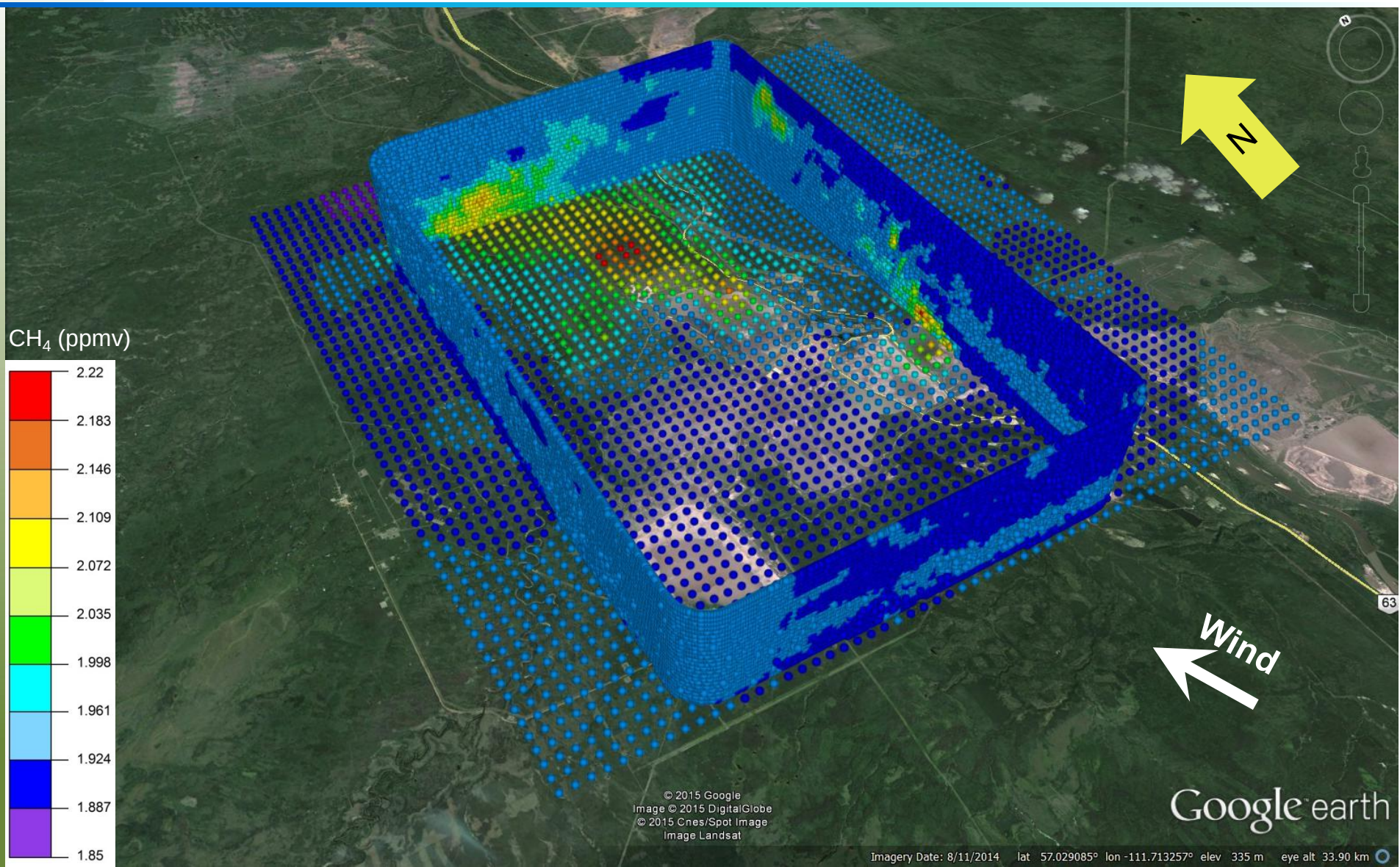
Particles, 1-10 sec

- AMS: composition
- SP2: rBC
- CPC, UHSAS, PCASP
- FSSP300: counts and size

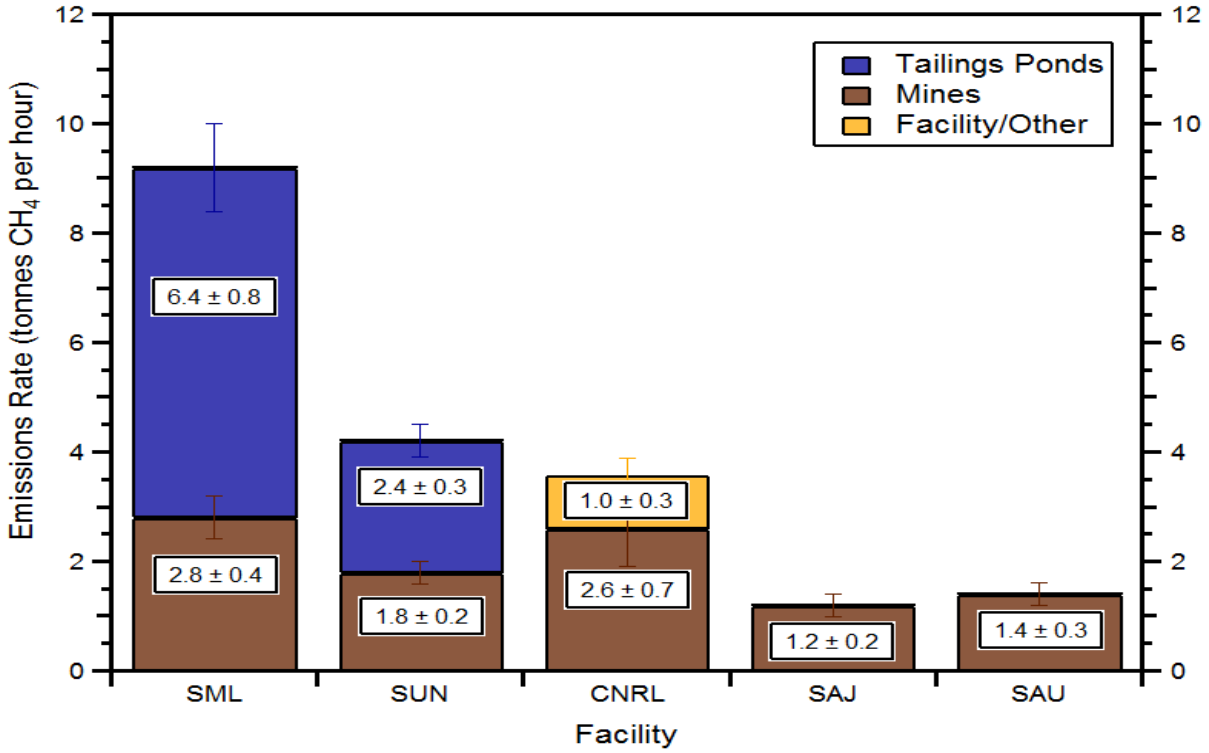
Meteorological and other state parameters

- 3-D wind spd/dir, T, P, RH
- Position (long, lat, alt)
- Turbulence

CH_4 mixing ratio distributions for a flight around the Syncrude Mildred Lake facility

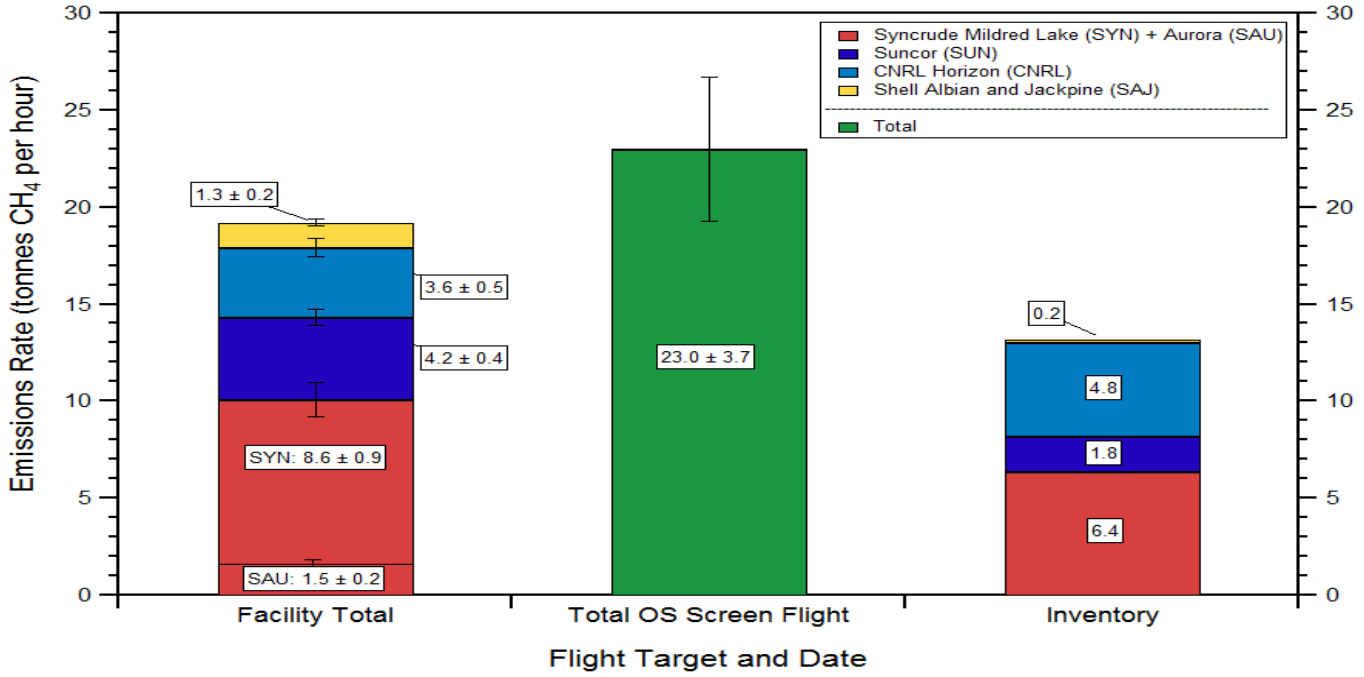


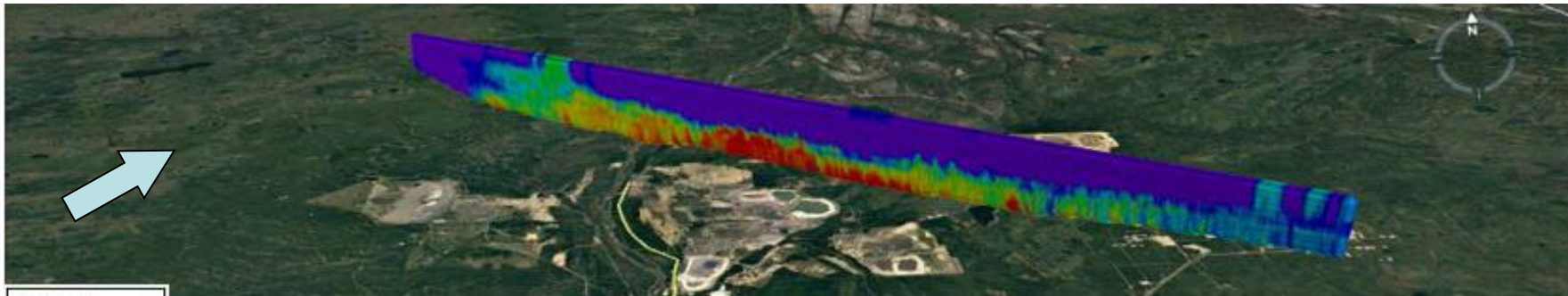
CH_4 emission rates of OS surface mining facilities determined from the aircraft flights



Baray, S., A. Darlington, M. Gordon, **K.L. Hayden**, Amy Leithead, S.-M. Li, P.S.K. Liu, R.L. Mittermeier, J. O'Brien, R. Staebler, M. Wolde, D. Worthy, S.G. Moussa, **R. McLaren**, Quantification of Methane Sources in the Athabasca Oil Sands Region of Alberta by Aircraft Mass-Balance, **Atmos. Chem. Phys. https://doi.org/10.5194/acp-2017-925, 2017.**

Comparison of measurements to estimates in Canada's Greenhouse Gas Reporting Program





Results - CH_4 emissions from oil sands facilities

- Total measured CH_4 emission rates from 5 surface mining facilities is 19.2±1.1 tonnes CH_4 hr^{-1}
- Tailings ponds accounted for 45% of CH_4 emissions, while mine faces contributed 50%
- The measured hourly CH_4 emission rate from all facilities in the AOSR is 48±8% higher than the hourly rate for 2013 extracted from the Canadian Green House Gas Reporting Program (converted from annual rate)

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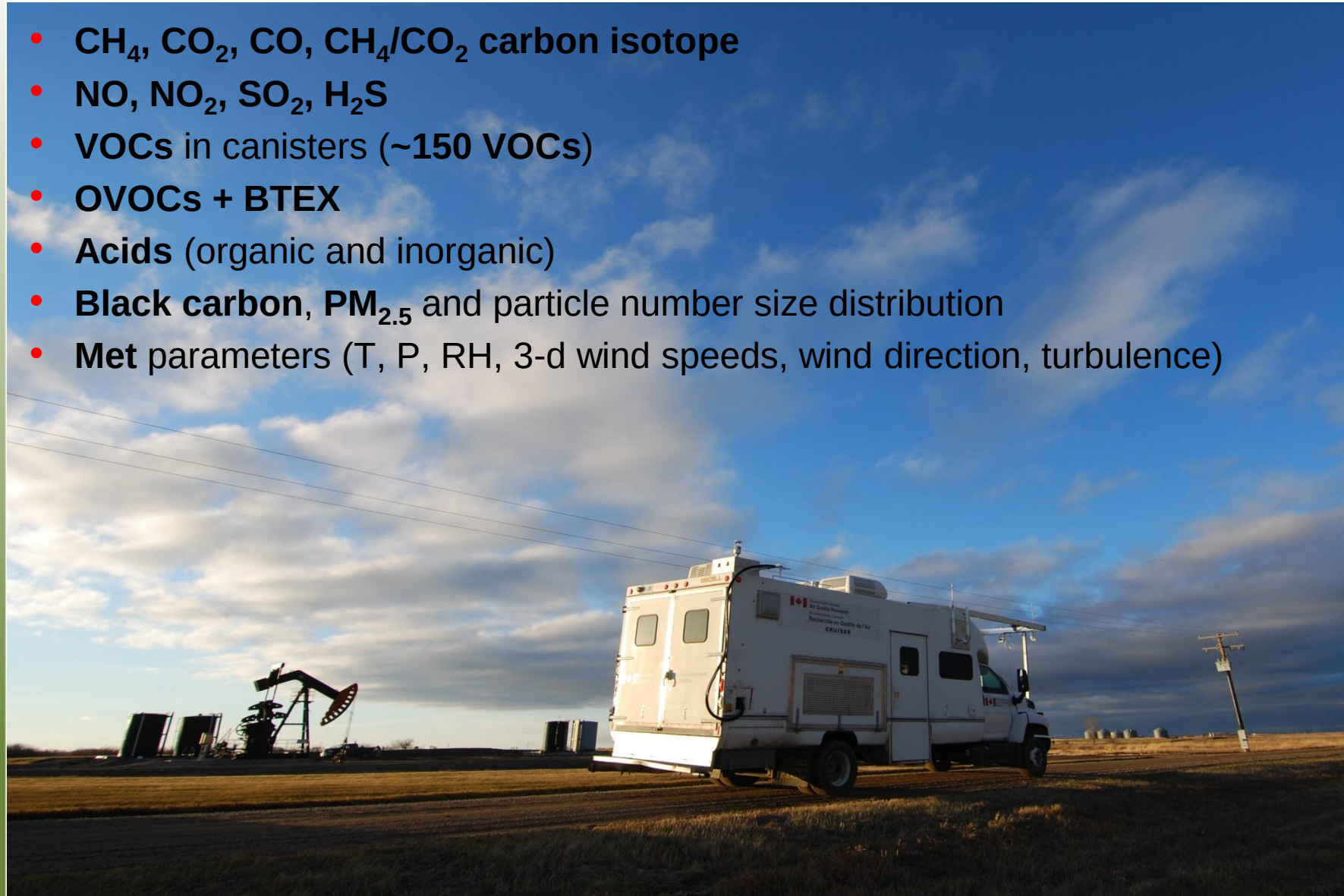
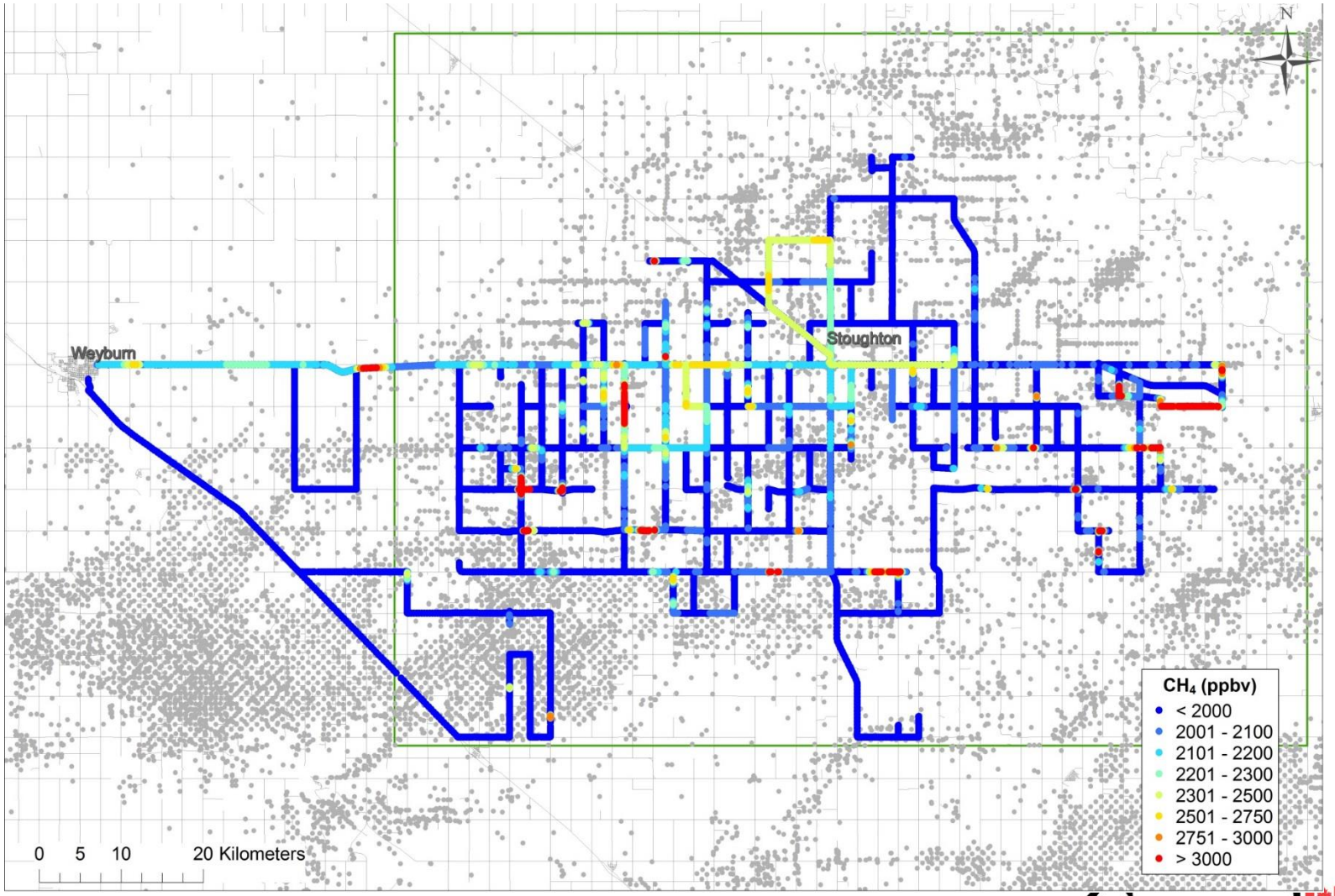
Mobile lab measurements - Saskatchewan 2015

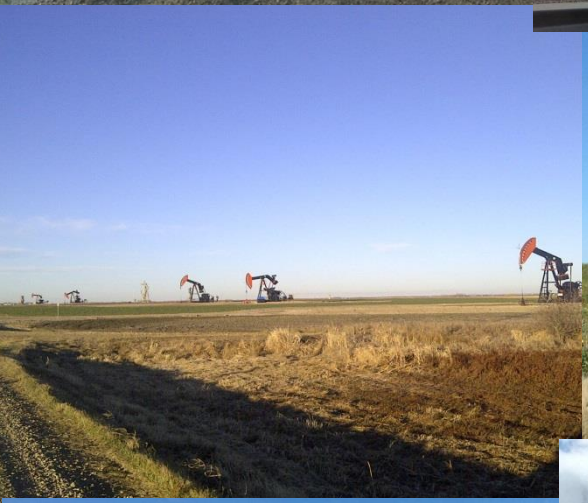
- **CH_4, CO_2, CO, CH_4/CO_2 carbon isotope**
- **NO, NO_2, SO_2, H_2S**
- **VOCs** in canisters (**~150 VOCs**)
- **OVOCs + BTEX**
- **Acids** (organic and inorganic)
- **Black carbon**, **$PM_{2.5}$** and particle number size distribution
- **Met** parameters (T, P, RH, 3-d wind speeds, wind direction, turbulence)



CH_4 emissions mapping in the Bakken region

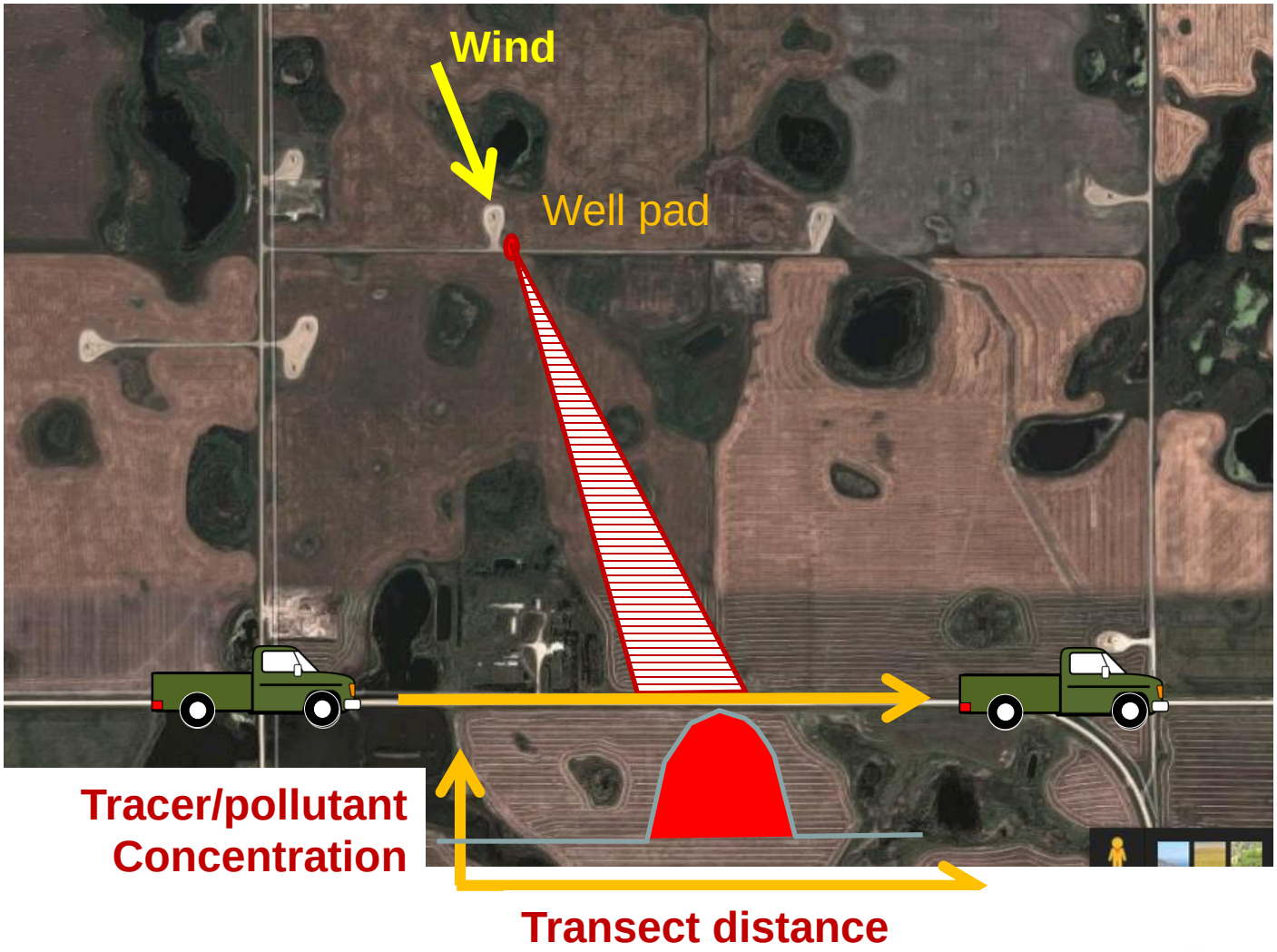




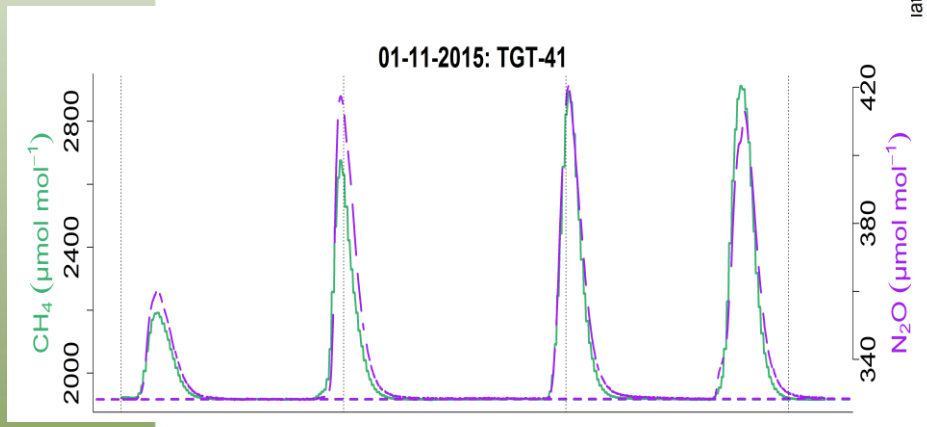






Emissions quantified using 2 methods:
1. Known tracer release (at 41 accessible sites)



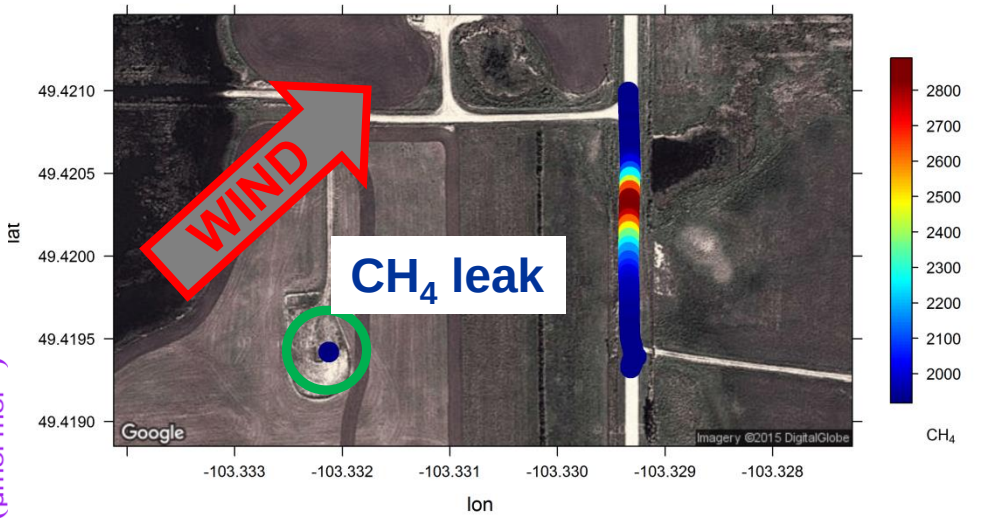
Tracer release experiment results

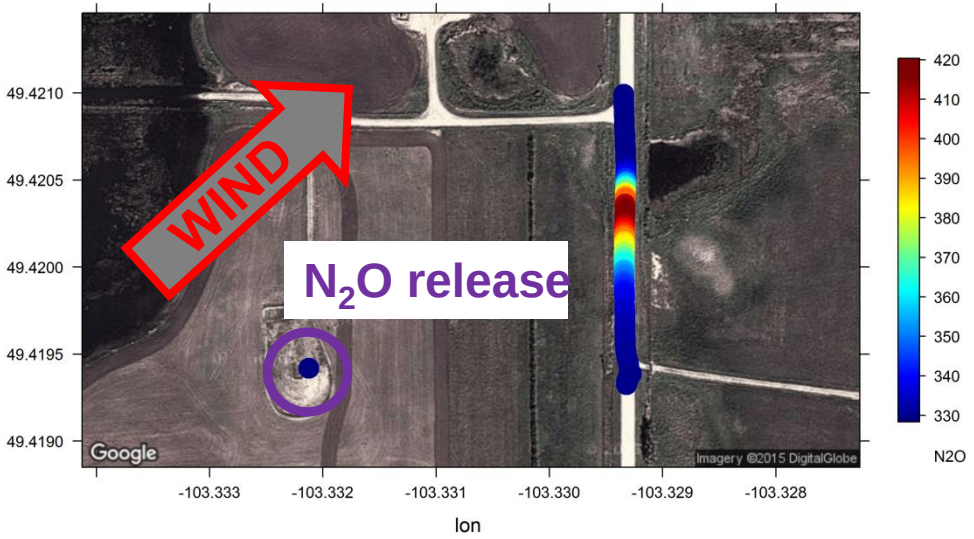


Transect1 Transect2 Transect3Transect4

CH_4 and **N_2O** measured for 4 separate transects are all highly correlated.

Transect 3





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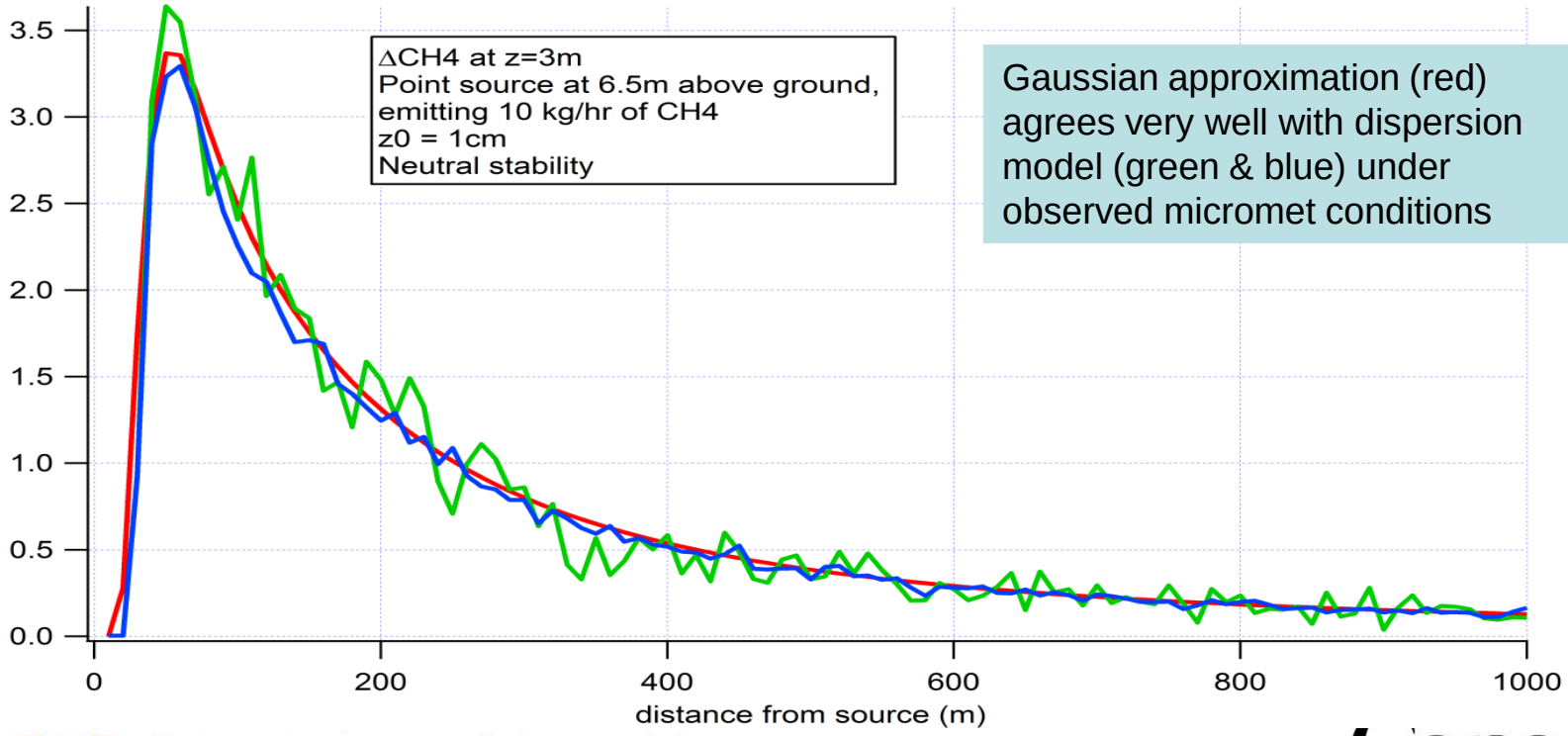
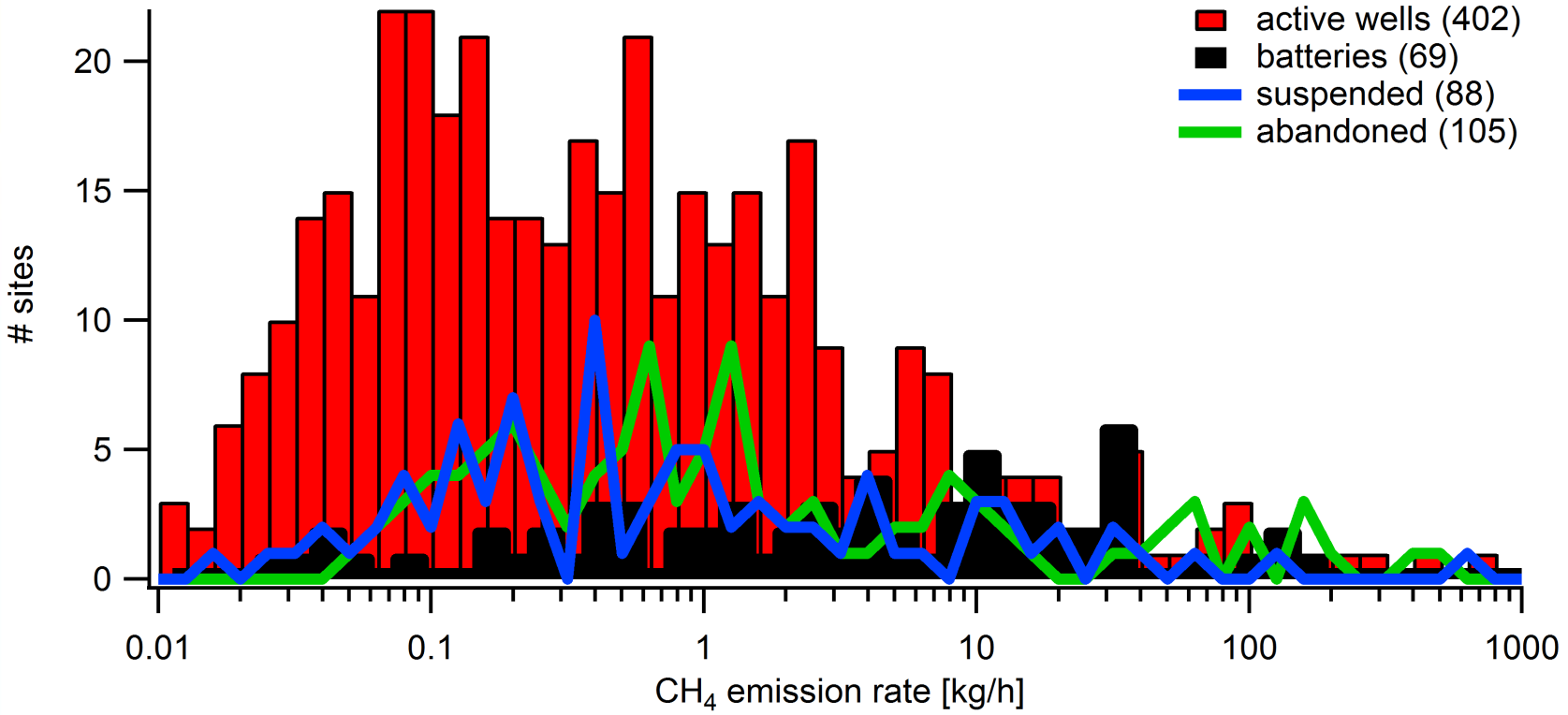
2. Gaussian dispersion (664 sites)

- For sites that were not accessible, a Gaussian dispersion model was used to relate the observed peak concentration (ΔCH_4) to the emission rate
- This model was verified with data from the N_2O release sites and tested against a more sophisticated Lagrangian stochastic dispersion model



Gaussian approximation (red) agrees very well with dispersion model (green & blue) under observed micromet conditions

Dispersion method emission results



- Scaling to a regional level gives a CH4 emissions estimate of 49 t/hr
- Compare to reported energy production sector emissions for the province of 54 t/hr
- Given that the south-east region produces less than half of the province's oil, the inventory emission estimates are likely too low

Conclusions

- In-situ measurements can be used to support emission estimation reporting
  - Aircraft measurement approach provides a useful method to estimate integrated emissions over a large facility (i.e., oil sands surface mining) and over regions with large numbers of dispersed facilities (e.g., oil fields)
  - Mobile lab measurement approach has the potential to provide site-based emission factors for upscaling to regional scales
- Comparison suggests that measured CH_4 emissions from oil sands surface mining facilities are higher than reported values by about 50%
- For the Bakken shale oil region
  - A significant fraction of oil wells have detectable CH_4 emissions
  - Regional emissions are dominated by a relatively small number of large emitters (such as wells or tanks)
  - Consistent with other studies, the mobile lab-based measurements show that emission estimates based on atmospheric observations are higher than bottom-up / reported emission estimates