QUANTIFICATION OF AREA FUGITIVE GHG EMISSIONS AT OIL SANDS MINES BY A NOVEL INVERSE DISPERSION MODELLING (IDM)APPROACH

Redefining possible.

CPANS

Edmonton, AB

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Outline

GHG and Oil Sands

- Where?
- What?
- How ?

Ambient Monitoring +
Inverse Dispersion modelling (IDM)

- Concept
- Application
- Results
- Challenges

Conclusions

Oil Sands, Northern Alberta, Canada

By NormanEinstein - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=773312

A strategic resource for Canada & North America

9% of Canada GHG emissions; 0.13% world GHG

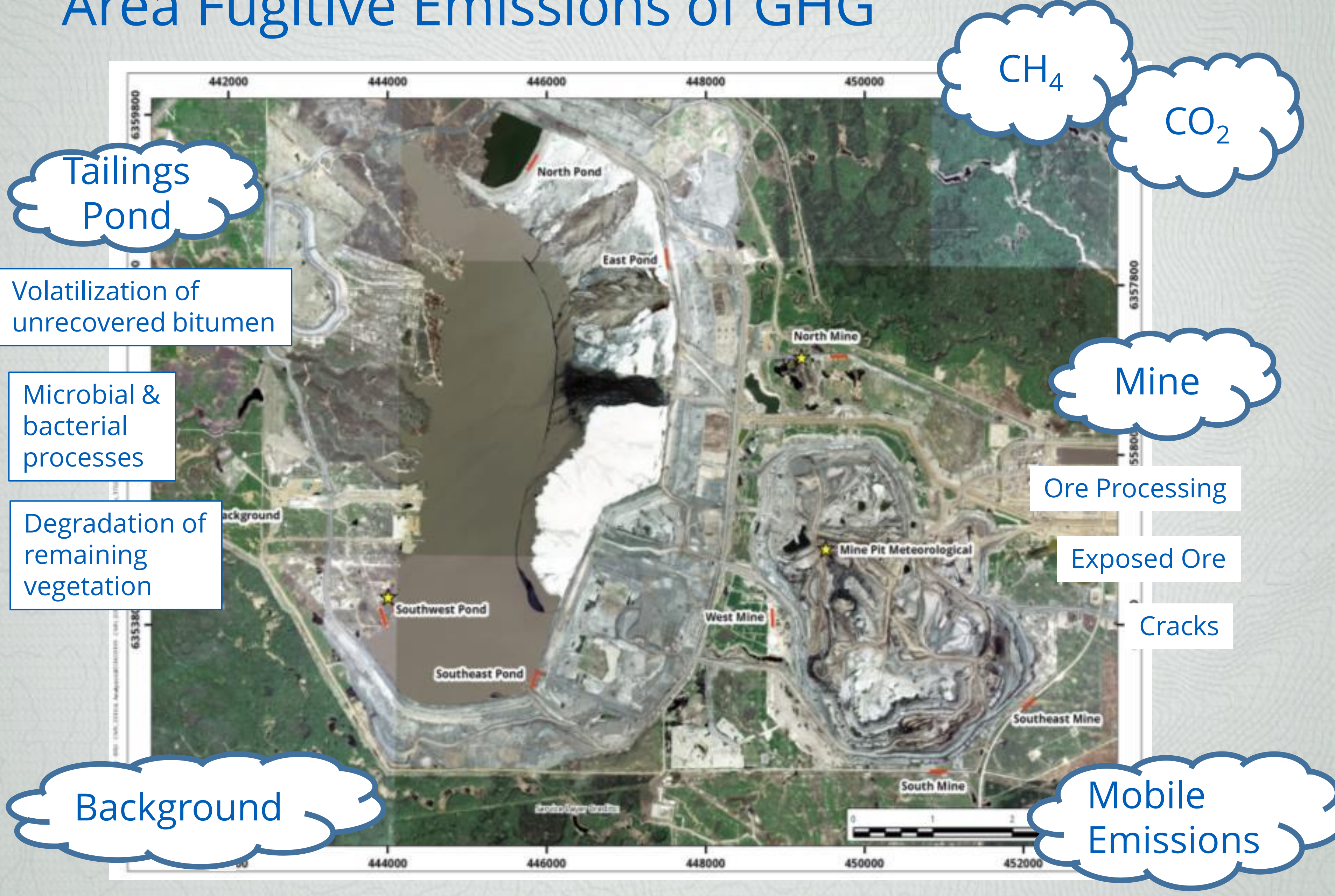
Current: 70MT/year
Cap: 100MT/year

GHG reduction = commitment by Alberta, Canada, and OG industry

Accurate estimate is critical

CAPP, http://www.canadasoilsands.ca/en/explore-topics/ghg-emissions
Environment and Climate Change Canada, 2016

Tailings Ponds and Open-Pit Bitumen Mines Area Fugitive Emissions of GHG



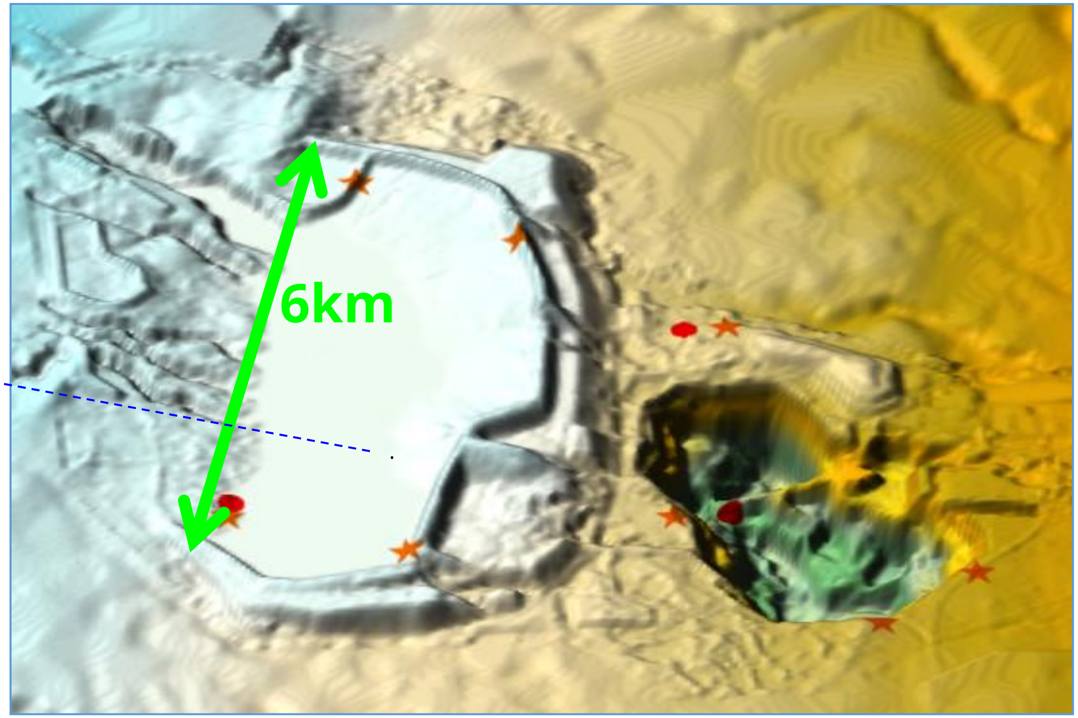
Open-Pit Bitumen Mine

Ore extraction and transport (T. Flesch)

Open-Pit Bitumen Mine

Ore extraction and transport
(T. Flesch)

The Challenge : large inhomogeneous sources



<u>Current Method</u>
30 minutes/year,
limited area coverage
(0.00004%!)

<u>Ideal Solution</u>
24/7 monitoring,
total area coverage

Traditional Method:
Isolation Flux Chambers

Pros:

Simple

Cons:

- Not spatially representative:

Typical tailings pond area ~ 10 10^6 m^2

Isolation Flux Chambers ~ 4 m^2 (0.13 m^2 x 30 samples)

0.00004% of the total area is sampled!

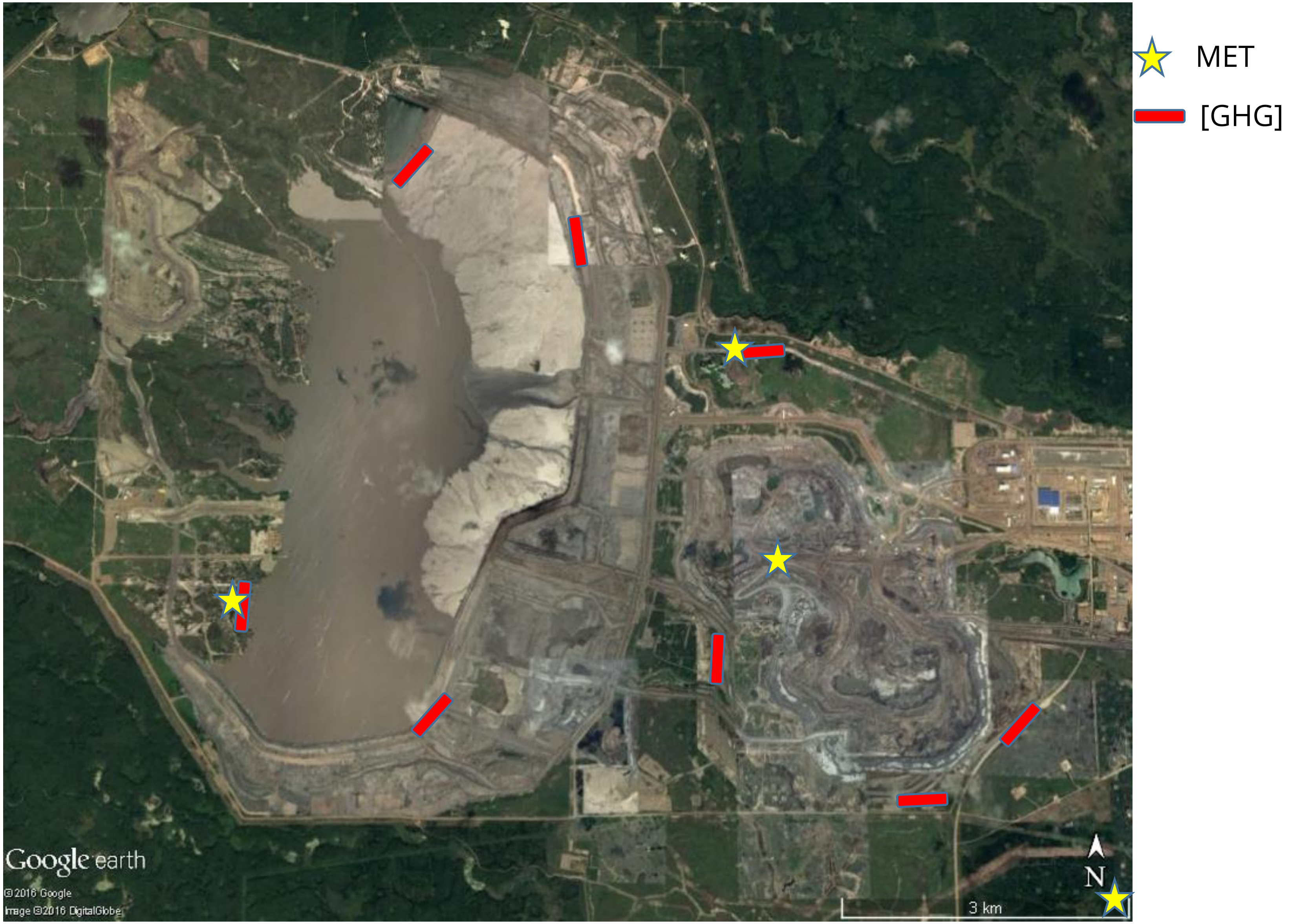
-Not temporally representative:

Effective measurement time : 1800 sec

Target: annual estimate (x 17,520)

- *In Situ*: interference with fluxes and operations; safety

Alternative Method:
Ambient Monitoring + IDM



Inverse Dispersion modelling

1. Monitor

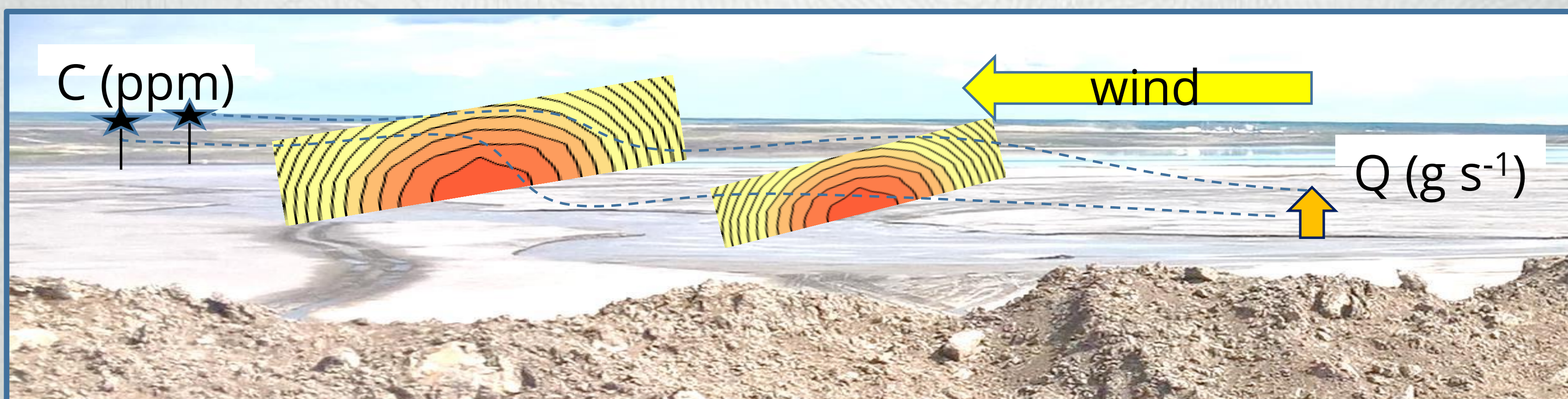
Ambient monitoring around pond/mine GHG concentrations + Meteorological Observations

2. Model

Emissions: First-guess
Meteorology: Obs./WRF/CALMET
Dispersion: CALPUFF

3. Invert

Reconcile modelling results with ***measured*** GHG concentrations => **actual GHG emissions**

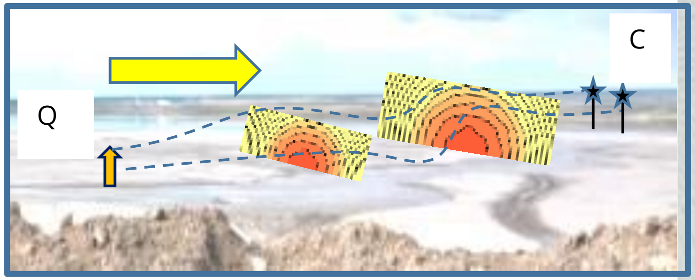


Alternative Method: Ambient Monitoring and IDM

Pros:

- Spatially representative:

- Varying wind directions and multiple monitoring sites
  => whole area source is sampled



- Temporally representative:

- 2-week field survey
- Potential for seasonal/continuous year-long monitoring

- **Safer:**
  - Edge of pond and mine => little interference with operations

Challenges:

- Small signal/noise ratio for CO_2 => sensors!
- Isolate the source impact from background, outfall, and mobile source contributions

Monitoring Equipment

CO_2/CH_4 lasers (2015)

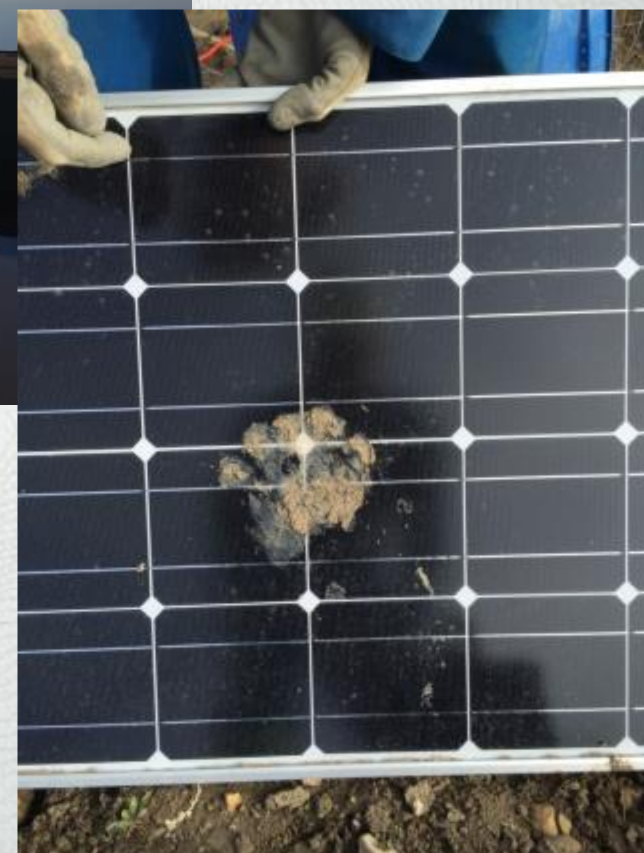
CO_2/CH_4 lasers (2016)

Sonic Anemometer

Monitoring Equipment

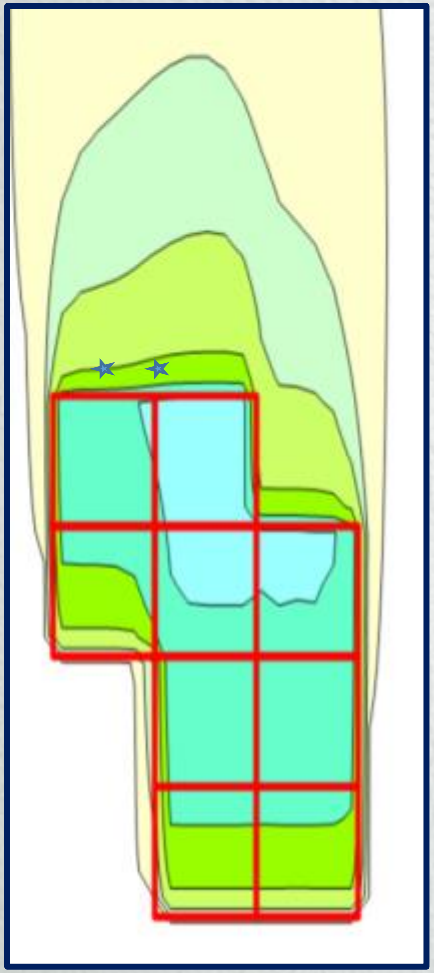
FTIR + sonic
(T. Flesch)

UltraPortable
Gas Analyzer
(LosGatosResearch)



Solar Panel
Bear Paw

Inverse Dispersion Modelling



- **CO_2 - CH_4: passive tracers**
  - ⇒ area source impact is a linear function of the emission rates
  - ⇒ fractional contributions with unit emission rates = fractional contributions with actual emission rates ($F_{i,n}$)
- **Run dispersion model (CALPUFF) with unit emission rates (and local meteorology)**
- **Measure actual impact with actual emission rates**
- **Invert**

Modelling

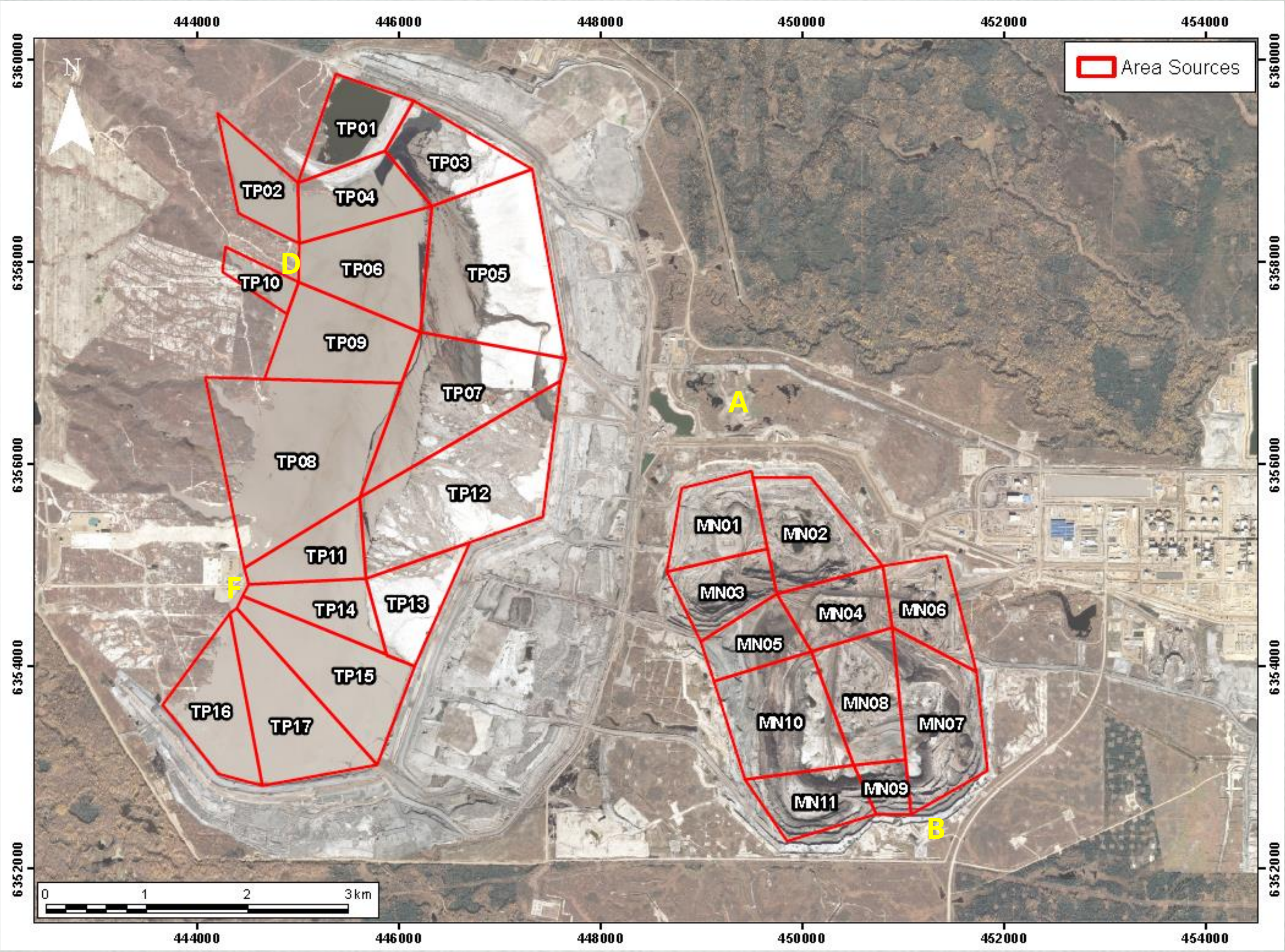
$$P_n = \sum_{i=1}^{N} F_{i,n}\, 1$$

Actual

$$C_n = \sum_{i=1}^{N} F_{i,n}\, Q_i$$

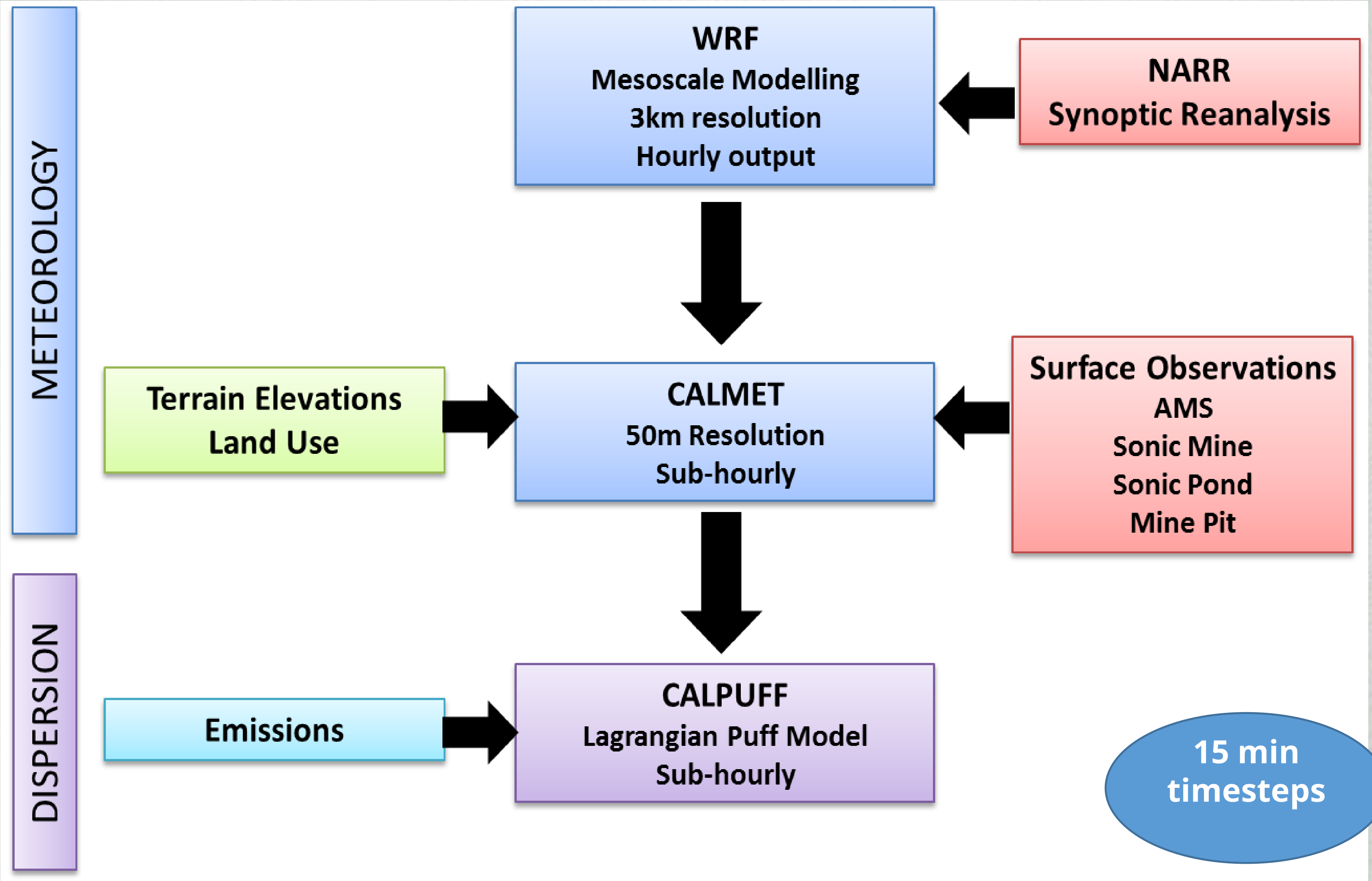
Same $F_{i,n}$

Monitoring and modelling Setup

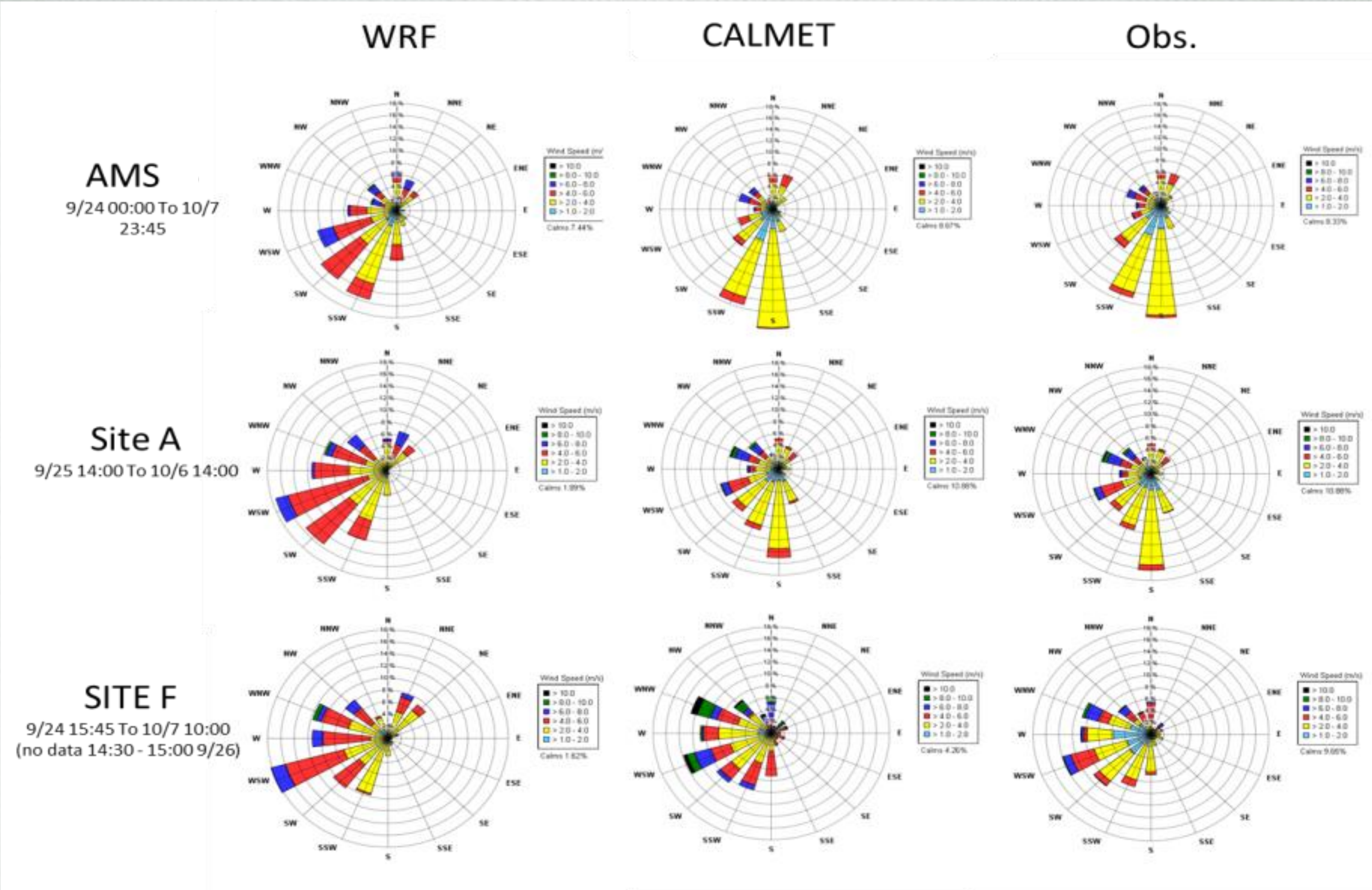


2015
Campaign

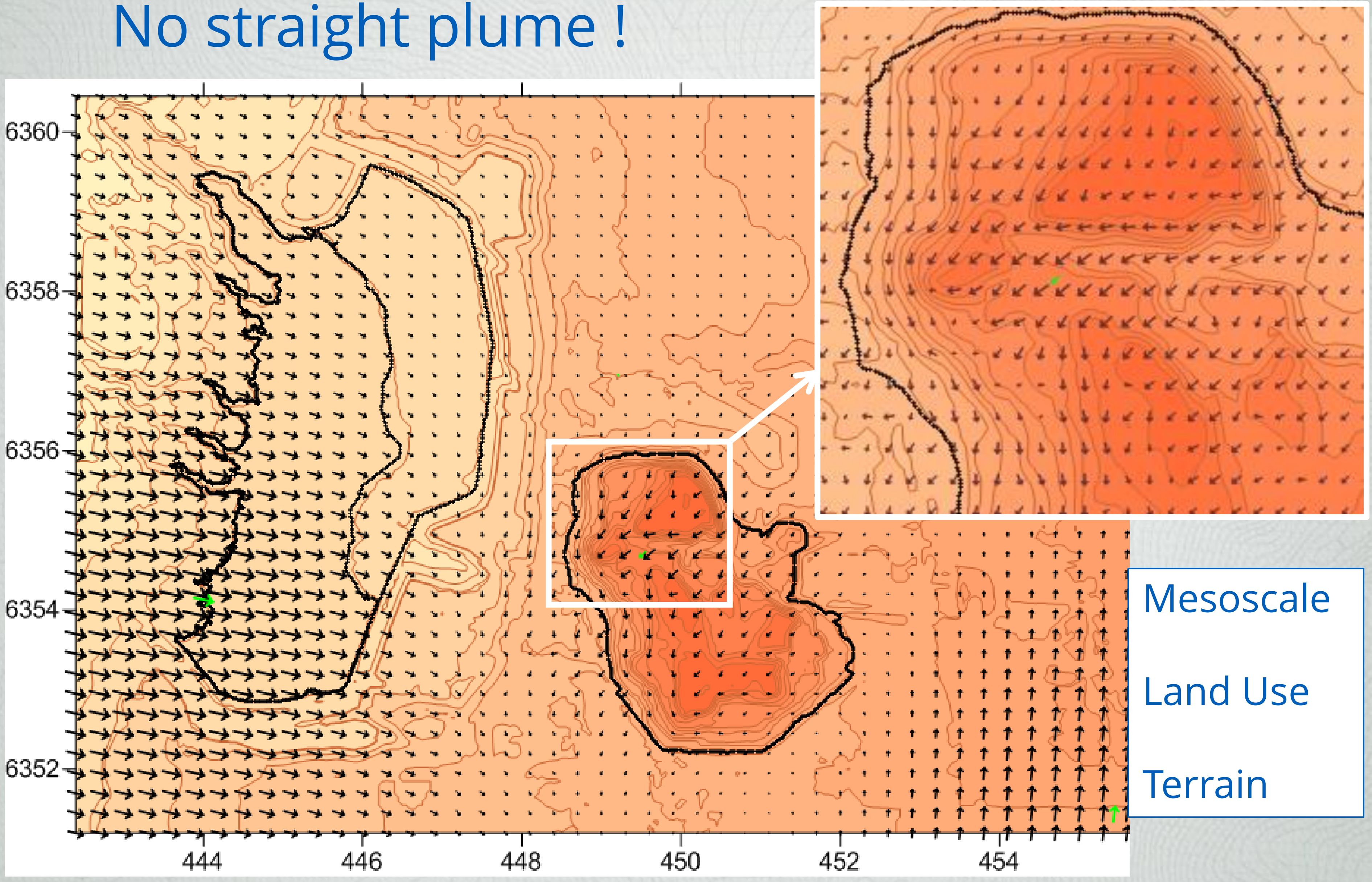
Meteorology : Advection + Turbulence



Meteorology



Spatially variable meteorology
No straight plume !

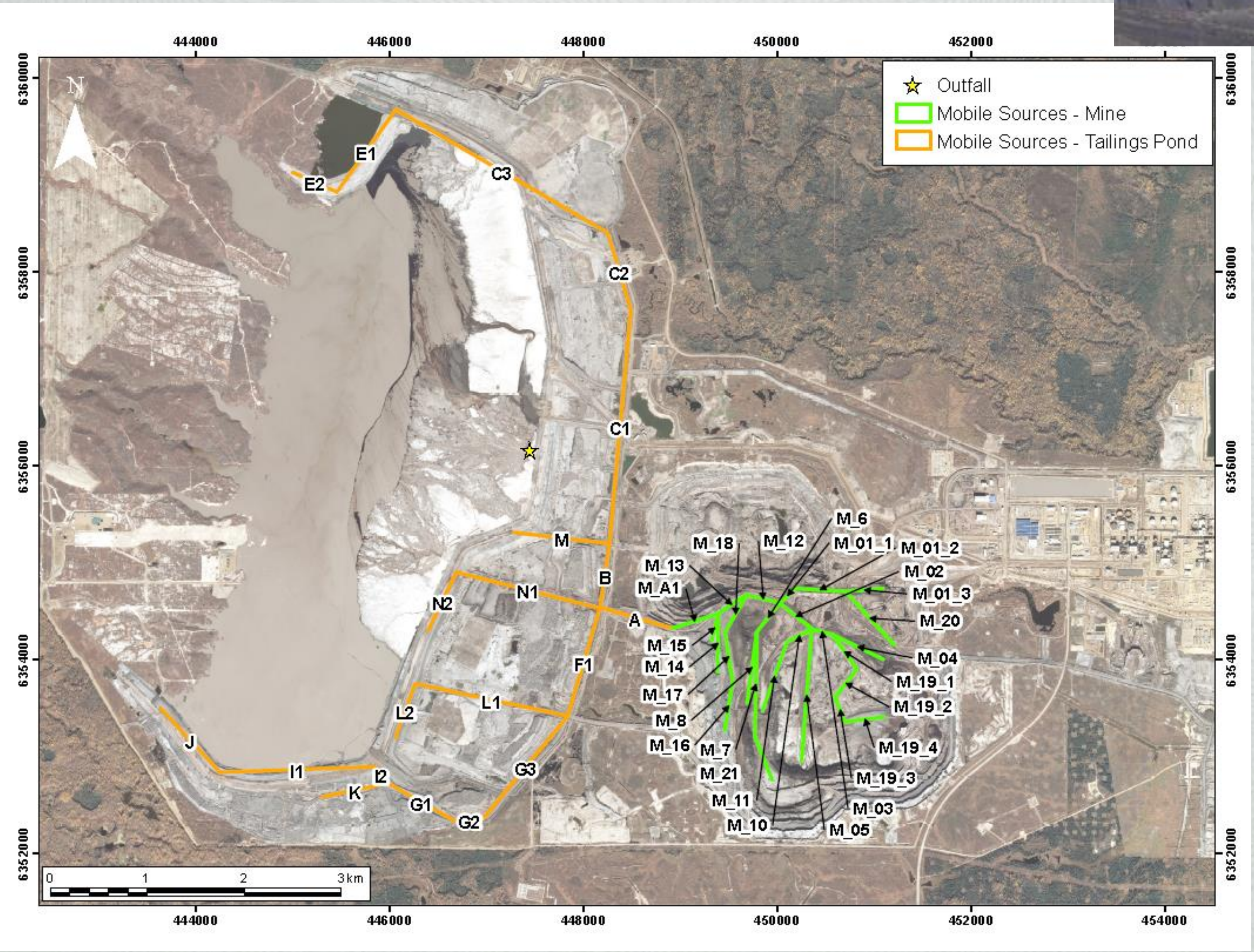


Mesoscale

Land Use

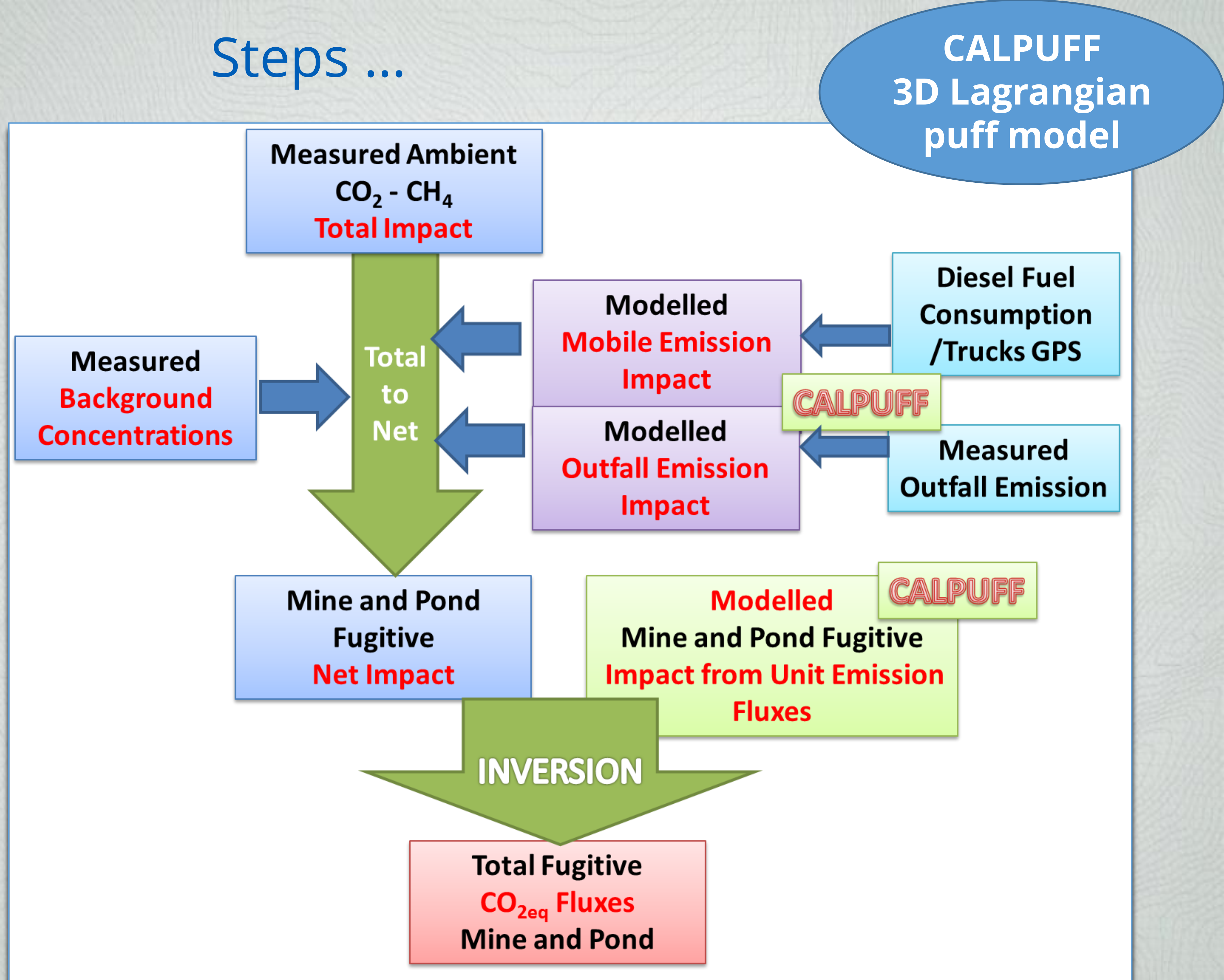
Terrain

Mobile Source Emissions



2015
Campaign

Steps …


CALPUFF
3D Lagrangian
puff model
Measured Ambient
CO2 - CH4
Total Impact
Measured
Background
Concentrations
Total
to
Net
Modelled
Mobile Emission
Impact
Diesel Fuel
Consumption
/Trucks GPS
CALPUFF
Modelled
Outfall Emission
Impact
Measured
Outfall Emission
Mine and Pond
Fugitive
Net Impact
CALPUFF
Modelled
Mine and Pond Fugitive
Impact from Unit Emission
Fluxes
INVERSION
Total Fugitive
CO2eq Fluxes
Mine and Pond

Inversion

2015:

- **Fitting QQ distribution** (paired in space/magnitude)
  - Regression
- **Standard Deviation:** based on observation uncertainty

2016:

- **Bayesian Statistical Approach**

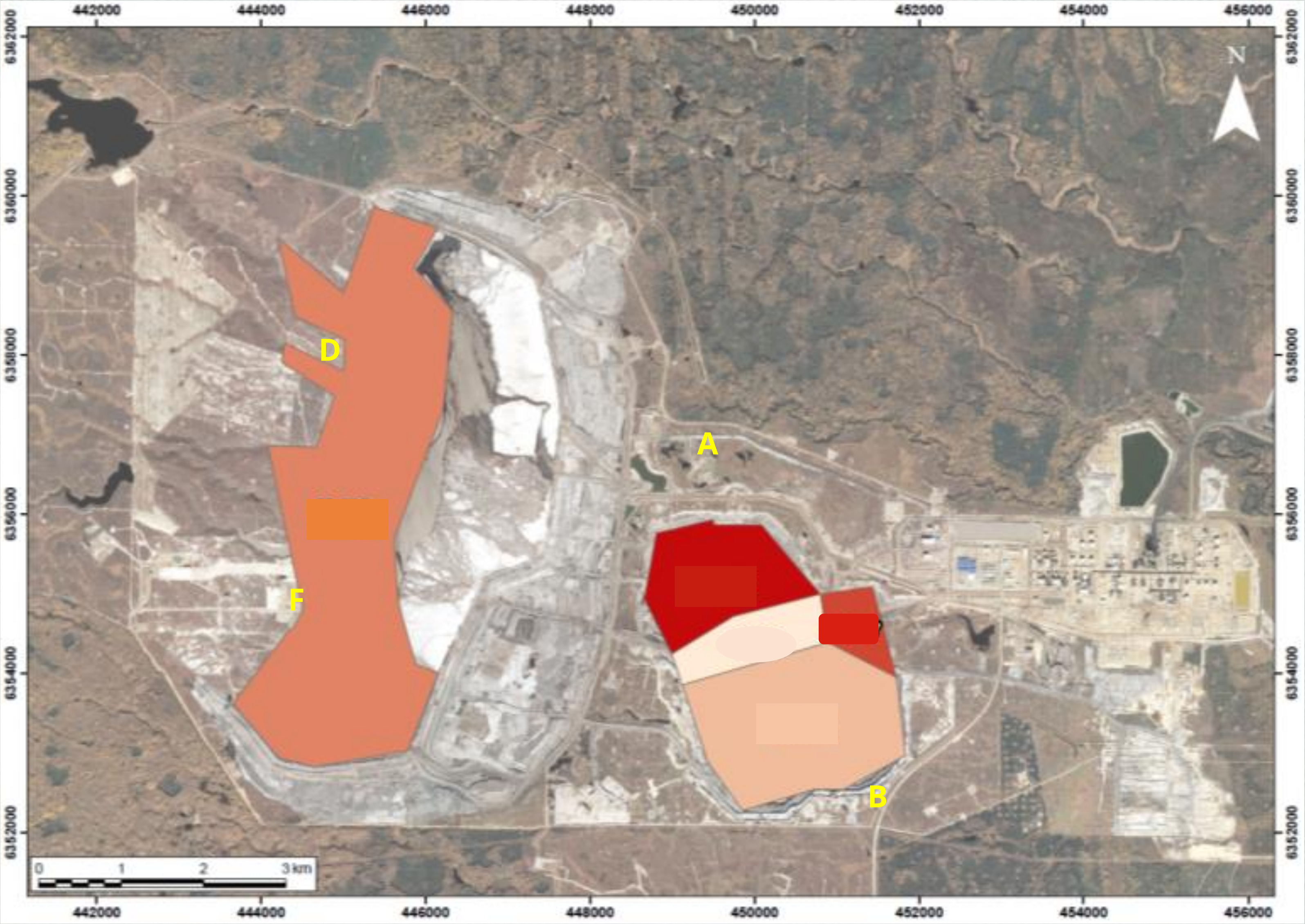
- **Fitting Timeseries** (paired in time and space)

- **Constraints:**
  - Positive emission fluxes

- **Standard Deviations based on uncertainties**
  - Observations & Modelling

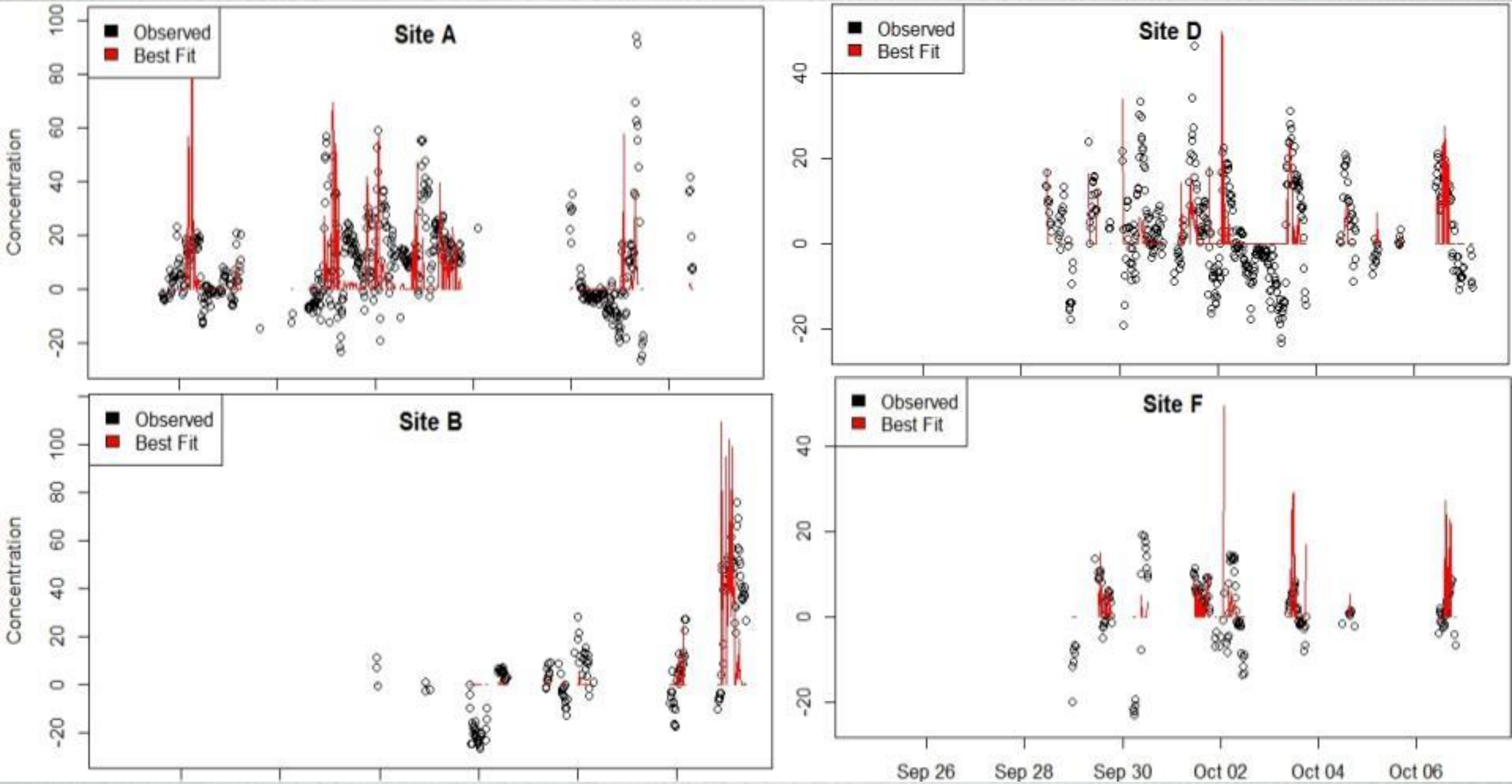
Annual CO_2 Emissions

2015



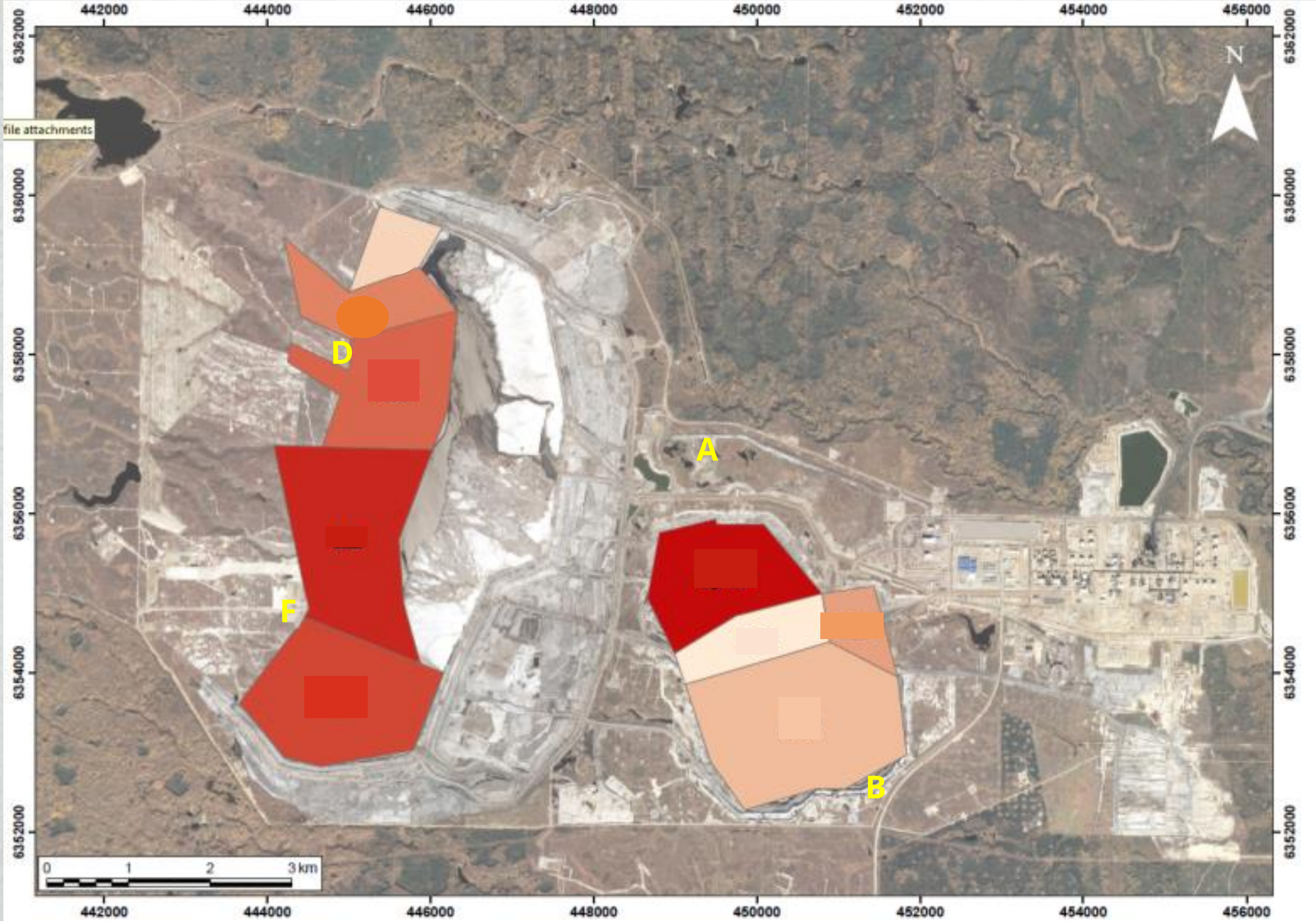
Validation – CO_2

2015



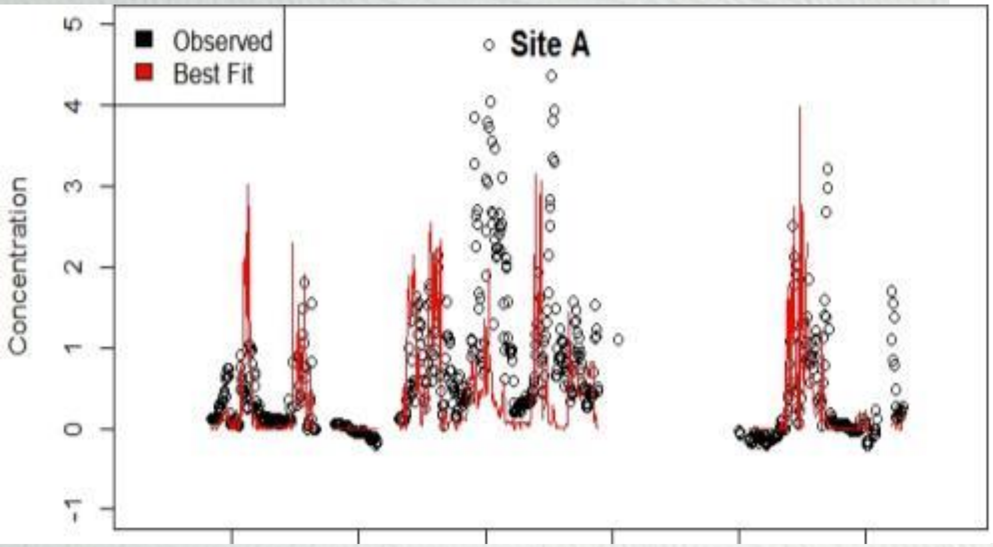
Annual CH_4 Emissions

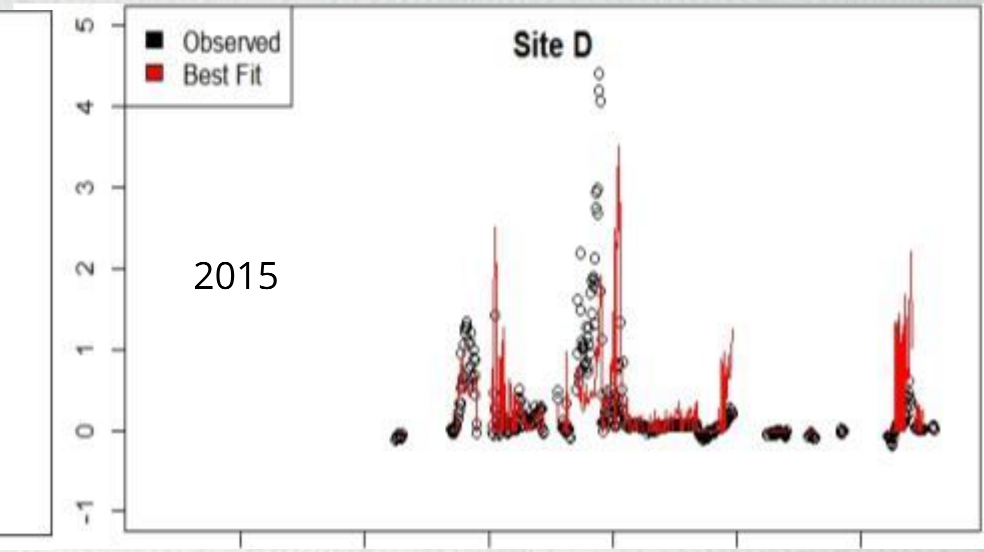
2015

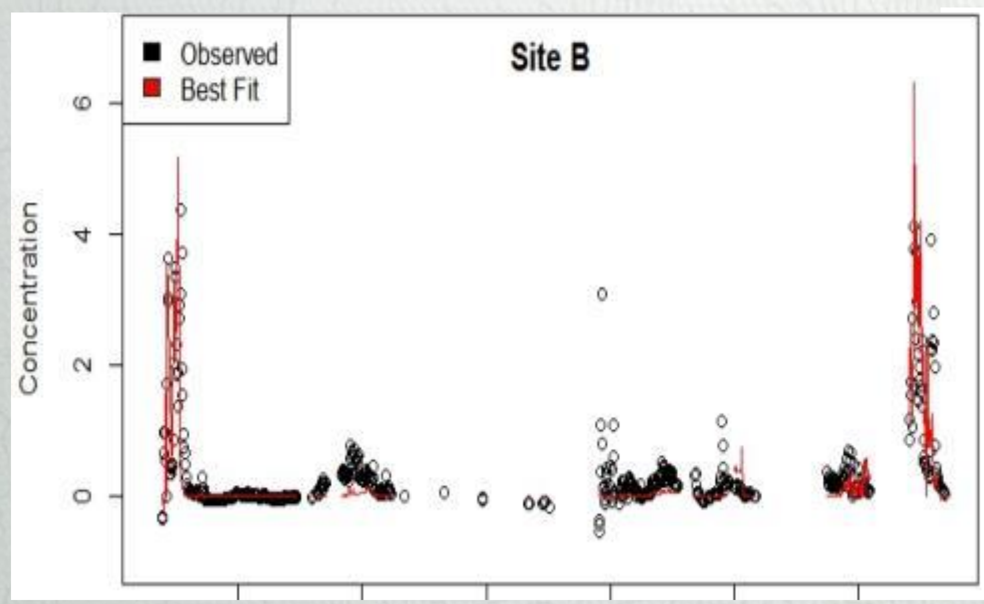


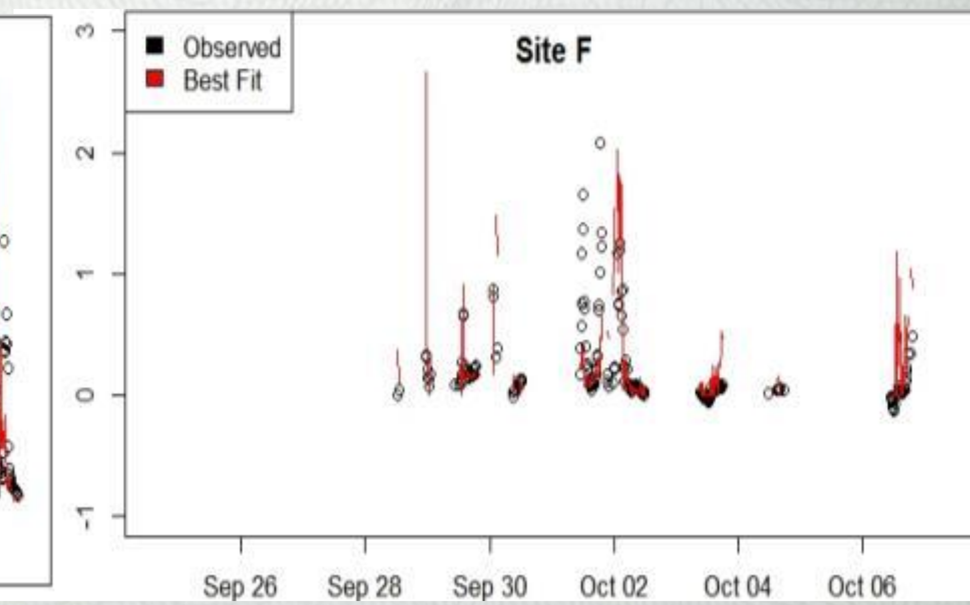
Tonnes

Validation – CH_4

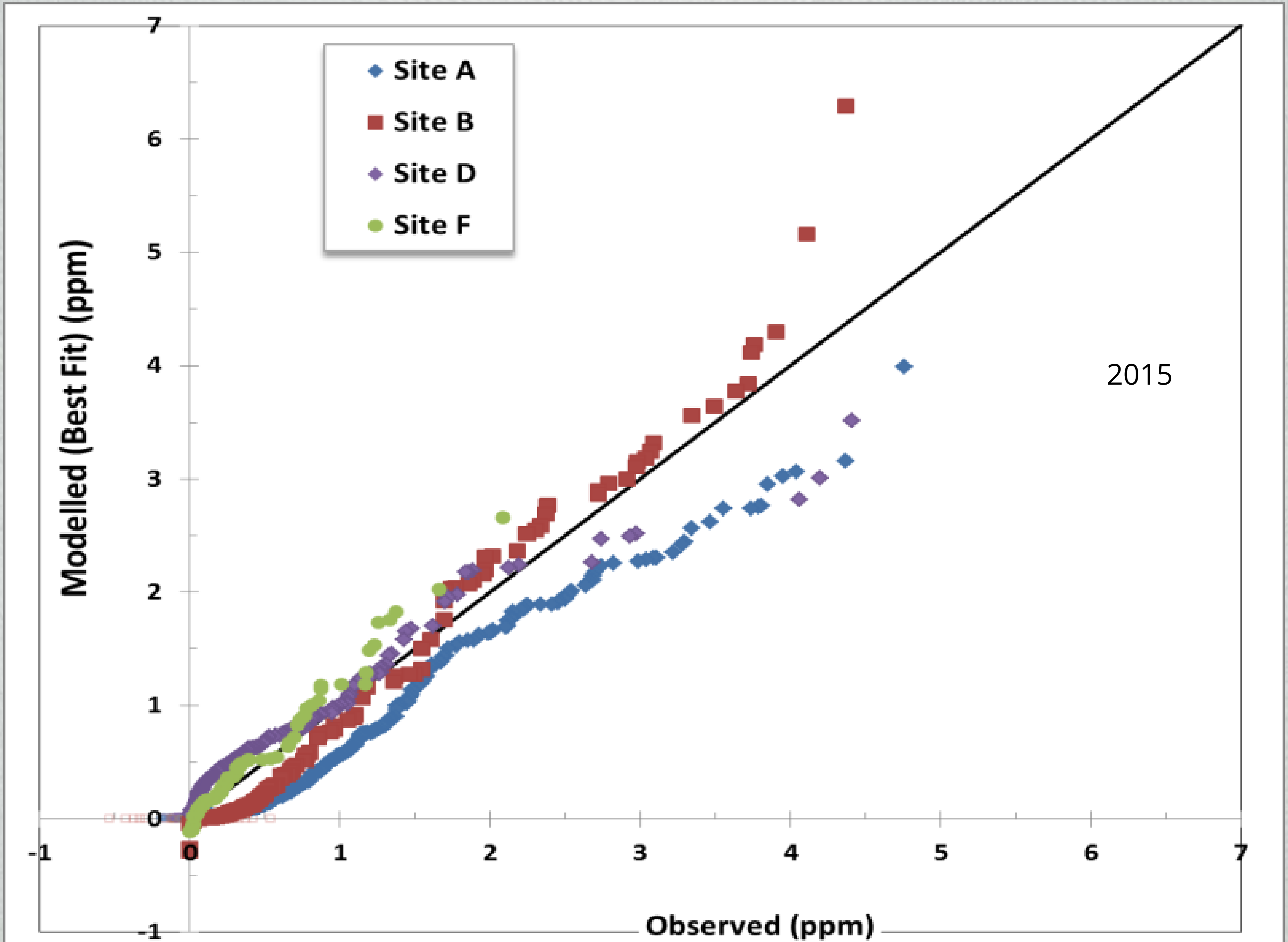








Validation – CH_4



Outcome

2015:

- IDM methodology proven for Oil Sands area fugitive emissions of GHG

2016:

- Enhanced background measurements
- Additional monitoring sites around mine and pond
- Additional bottom-pit met monitoring

2017-2019:

- TBD with plans for additional monitoring methods and ranking thereof

Challenges

2015:

- Mobile emissions: bulk not enough
- Background
- Monitoring sites (coverage)

2016:

- CO_2 barely above noise
- Lower CO_2 signal and higher laser noise (not a good combo…)
- Weather

Inversion:

- Pairing time/space uncertainty

CH_4
Signal ~ 1-5ppm
Background ~2ppm
Noise ~0.7ppm

CO_2
Signal ~ 15-90 ppm
Background ~390-450ppm
Noise ~7-16 ppm (laser)

Year	Net CO_2 Signal	Noise
2015	70-90 ppm	~7ppm
2016	15-20ppm	~16ppm

Conclusions

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IDM Method:

- **solid** alternative to flux chambers
- requires dispersion model that can deal with spatially variable meteorology (e.g. CALPUFF)
- **reliable** and **safe** (non-intrusive)
- can be paired with continuous monitoring for **more accurate annual** reporting, and long-term trends
- applicable to other sources (e.g. landfills, waste water, peat, feedlots ..)

Conclusions

CONCLUSIONS

GHG:

- CH_4 dominant – good signal
- CO_2: small compared to very large and variable background

Monitoring Equipment:

- Prefer portable gas analyzer (LGR) and FTIR
- Next generation open-path lasers
- Test others?

QUESTIONS?

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