Methane emissions from coal ventilation shafts in Silesia, Poland

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Further project partners: National Physical Laboratories (GB), SHELL (NL), Isoprime (GB), OonKAY (NL), Afvalzorg Deponie (NL), Viridor (GB), Whiffle Weather Finecasting (NL)

Why Upper Silesia Coal Basin?

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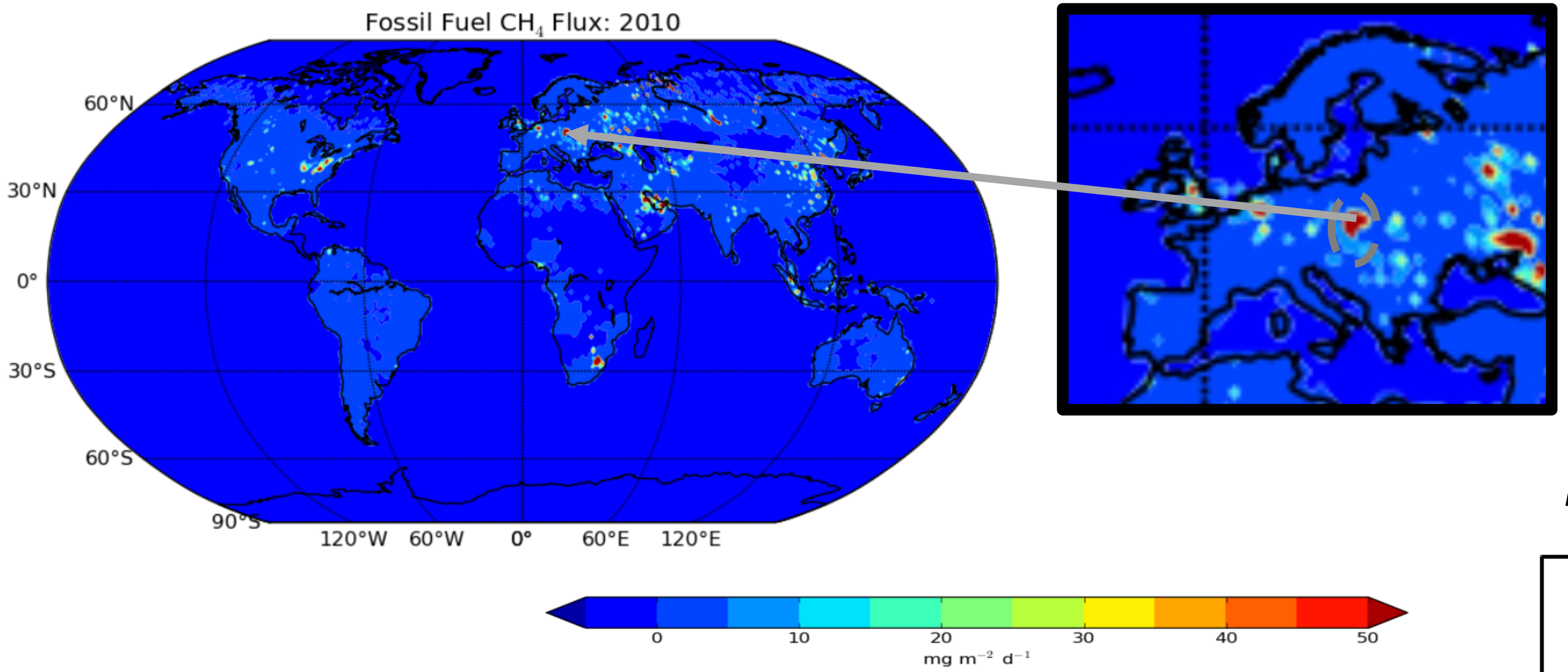

*Figure 1. a. Average estimated CH_4 fluxes at 1º x 1º km resolution**

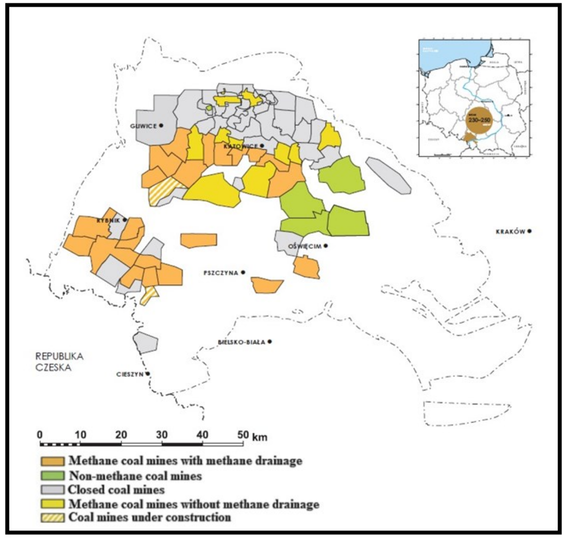

*Figure 2. Map of mining areas over the USCB***

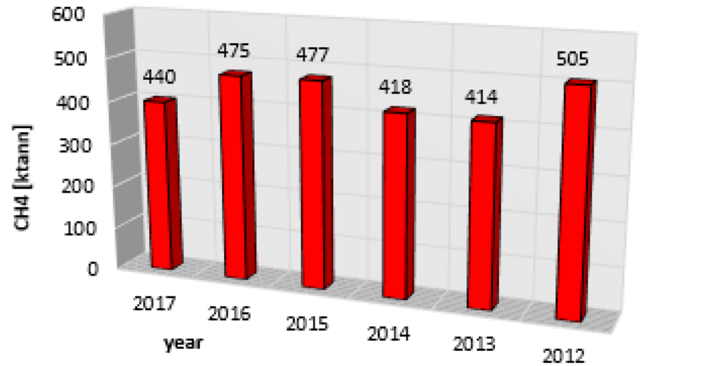

Figure 3. E-PRTR database yearly report of CH_4 from coal mine facilities

- **Upper Silesia Coal Basin (USCB) is the major European hotspot of CH_4 release (figure 1).**
- **The active or closed coal mines are spread over the USCB (figure 2)**
- **Yearly, the coal activities from USCB release to the atmosphere 440 kt CH_4 (E-PRTR 2017, figure 2)**
- **The problem is not only accurate CH_4 estimations across USCB, but also the proper identification of the sources**

- * *Carbon Tracker-CH_4 data (https://www.esrl.noaa.gov/gmd/ccgg/carbontracker-ch4)*
- *** Swolkień J. 2020. Polish underground coal mines as point sources of methane emission to the atmosphere*

Measurement deployment in the Upper Silesia Coal Basin(USCB)

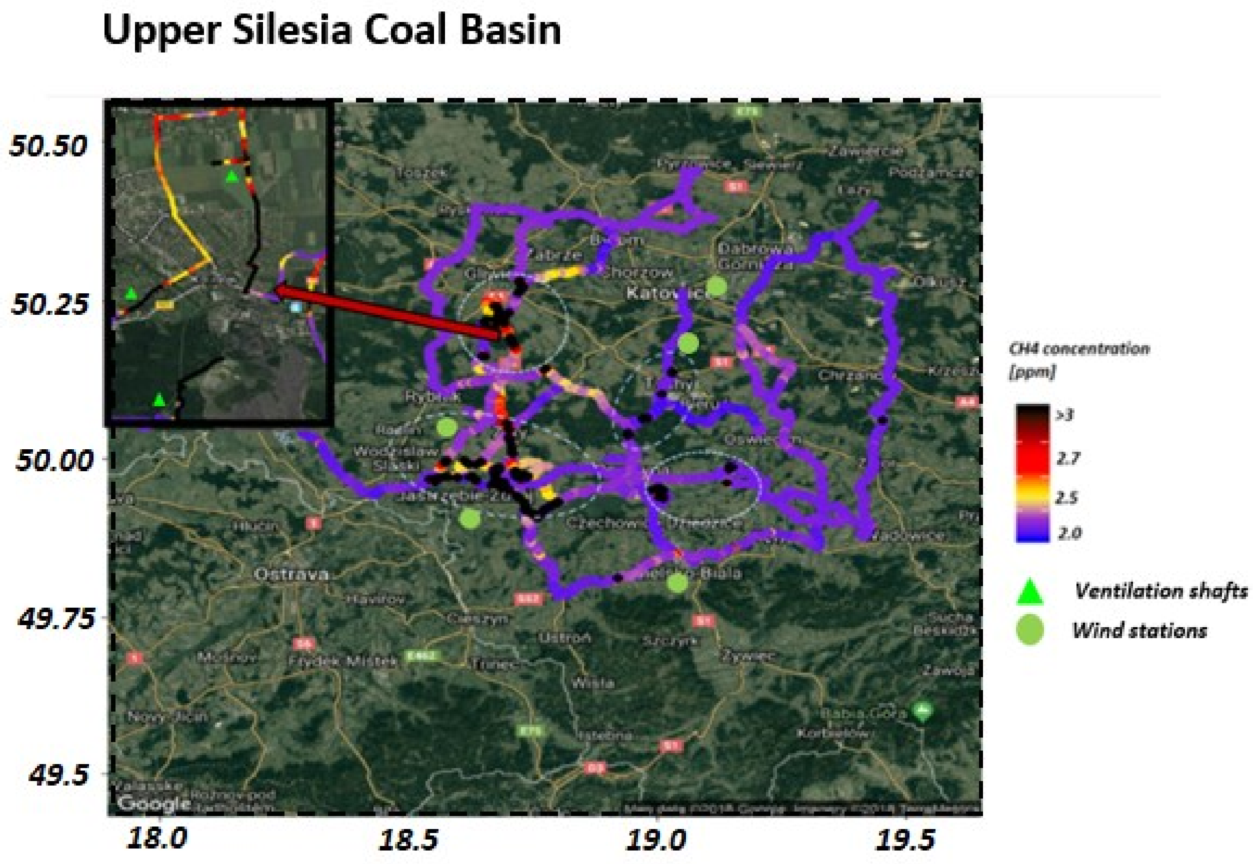

Figure 4. Mobile measurements around USCB.
Colour scale illustrates measured CH4 enrichment

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USCB: area of 5400km^2

- ➢ **22 active coal facilities over USCB**
- ➢ **Most of the coal mining facilities are with extremely high CH_4 emission rate: up to 63 kt ann (E-PRTR,2017*)**

Our measurements include

- **Mobile CH_4 measurements (van with CRDS analyser)**
  supplemented with
- **Wind data from**: 1. public wind stations
  2. WRF-GHG simulations
- **Gaussian plume model**
- **CH_4 isotopic information**: 1. δ 13CH4
  2. δ D

In order to quantify CH_4 flux
and
assign CH_4 isotope signature to the particular coal mining shafts

*https://prtr.eea.europa.eu/

Measurement deployment: equipment

1. CH_4 concentration

2. CH_4 isotopes: δD and δ13CH_4

a.

b.

Picarro G2201-i CRDS installed on van:

- *CH_4 concentration (precision 1ppb every 5s)*
- *$\delta^{13}CH_4$ (prec. 2‰ every 5 sec)*
- *Wind information (speed, direction)*
- *battery (24h operation)*
- *GPS location*

+

Bag samples measured in the laboratory by:

- *Picarro CRDS*
- *CF-IRMS (prec. 0.07 ‰ $\delta^{13}CH_4$ and 2 ‰ SMOW δD)*

Figure 5. a. Mobile platform with b. Picarro G2201-i CRDS analyser

a.

b.

*Figure 6. a.CF-IRMS in the laboratory **
b. Sample bags ready for isotopic analysis
**(Utrecht University equipment)*

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Measurement deployment: driving at different distances from the source

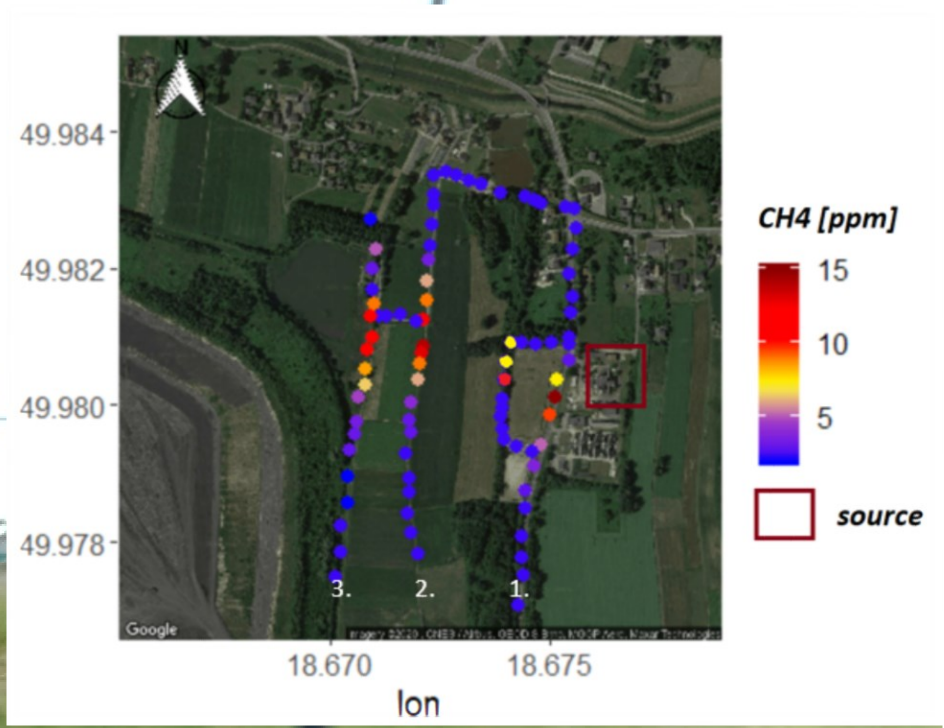

Figure 7. CH_4 plume intersect at different distances from the source

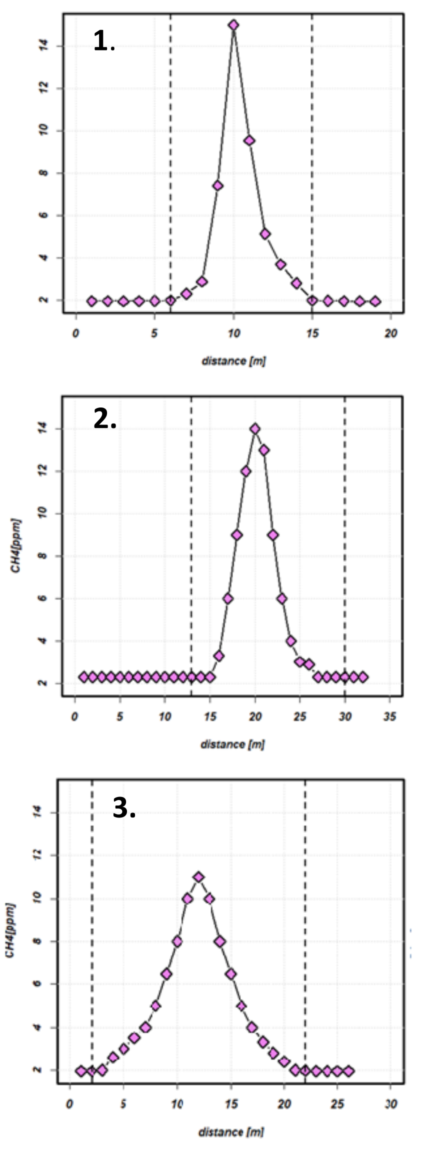

Figure 8. Measured CH_4 plume at different distances

In order to obtain emission estimates, we measured CH_4 plumes from coal mine shafts using public roads. (Figure 7).

When possible, the plumes were intersected several times at different distances in order estimate uncertainty.

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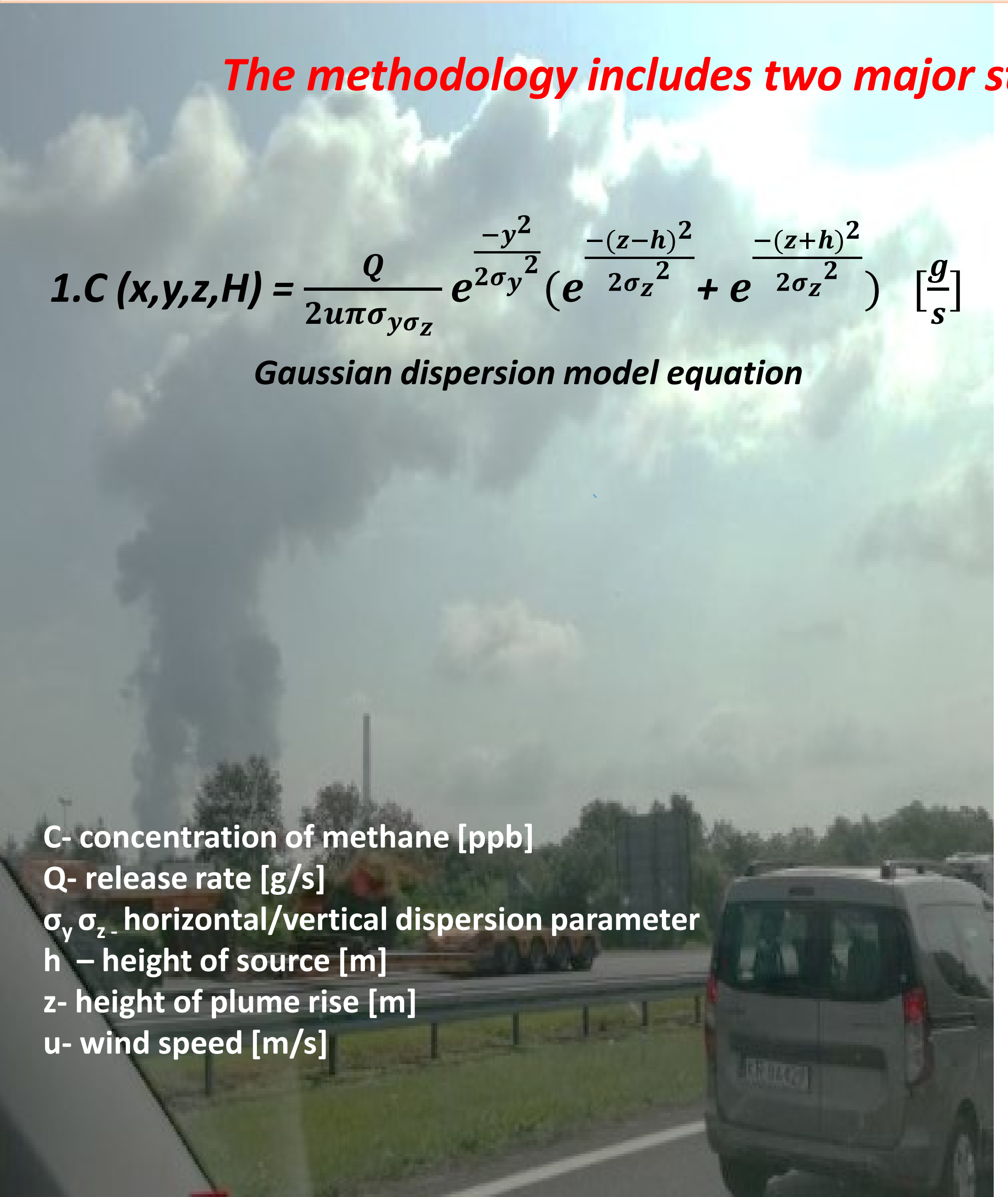
Methodology: flux calculations- Gaussian plume model



The methodology includes two major steps: 1. Fitting data onto the Gaussian plume model
2. Integrated measured and modelled data

$$1.C\,(x,y,z,H) = \frac{Q}{2u\pi\sigma_y\sigma_z} e^{\frac{-y^2}{2\sigma_y{}^2}} \left(e^{\frac{-(z-h)^2}{2\sigma_z{}^2}} + e^{\frac{-(z+h)^2}{2\sigma_z{}^2}}\right) \quad \left[\frac{g}{s}\right]$$

Gaussian dispersion model equation

C- concentration of methane [ppb]
Q- release rate [g/s]
σ_y σ_z - horizontal/vertical dispersion parameter
h – height of source [m]
z- height of plume rise [m]
u- wind speed [m/s]

$$2.Q = \frac{\int mesured,CH4}{\int model,CH4} * source\ strength \left[\frac{g}{s}\right]$$

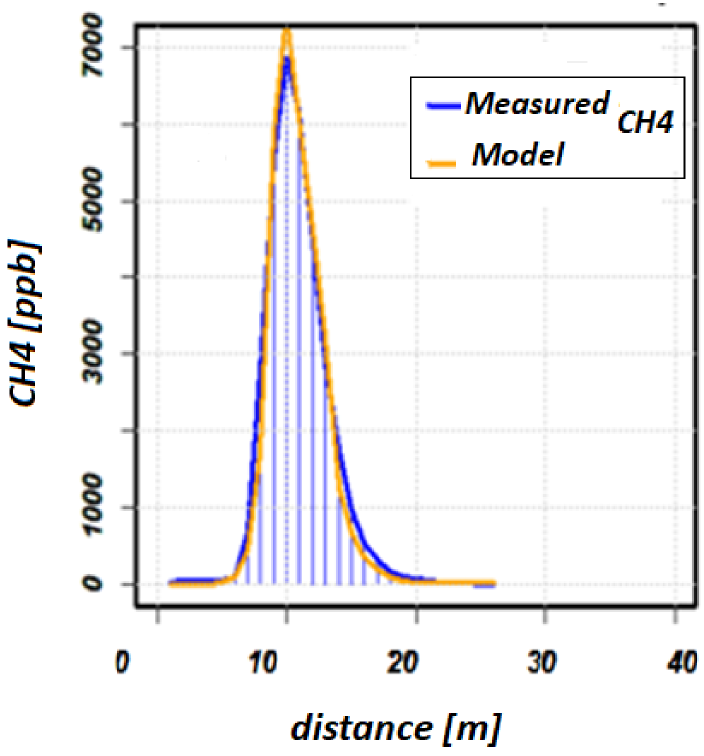
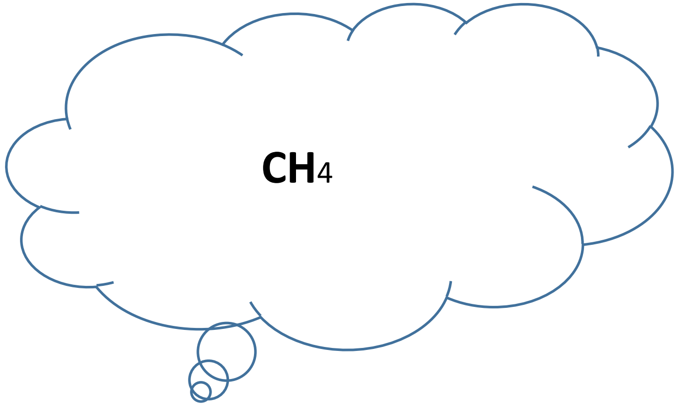


Figure 9. Measured data and model fit



$\int mesured, CH4$ -
area under obtained peak
$\int model, CH4$ -
area under modeling data
source strength –
input data of release rate [g/s]

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Results: plume intersect at different distances

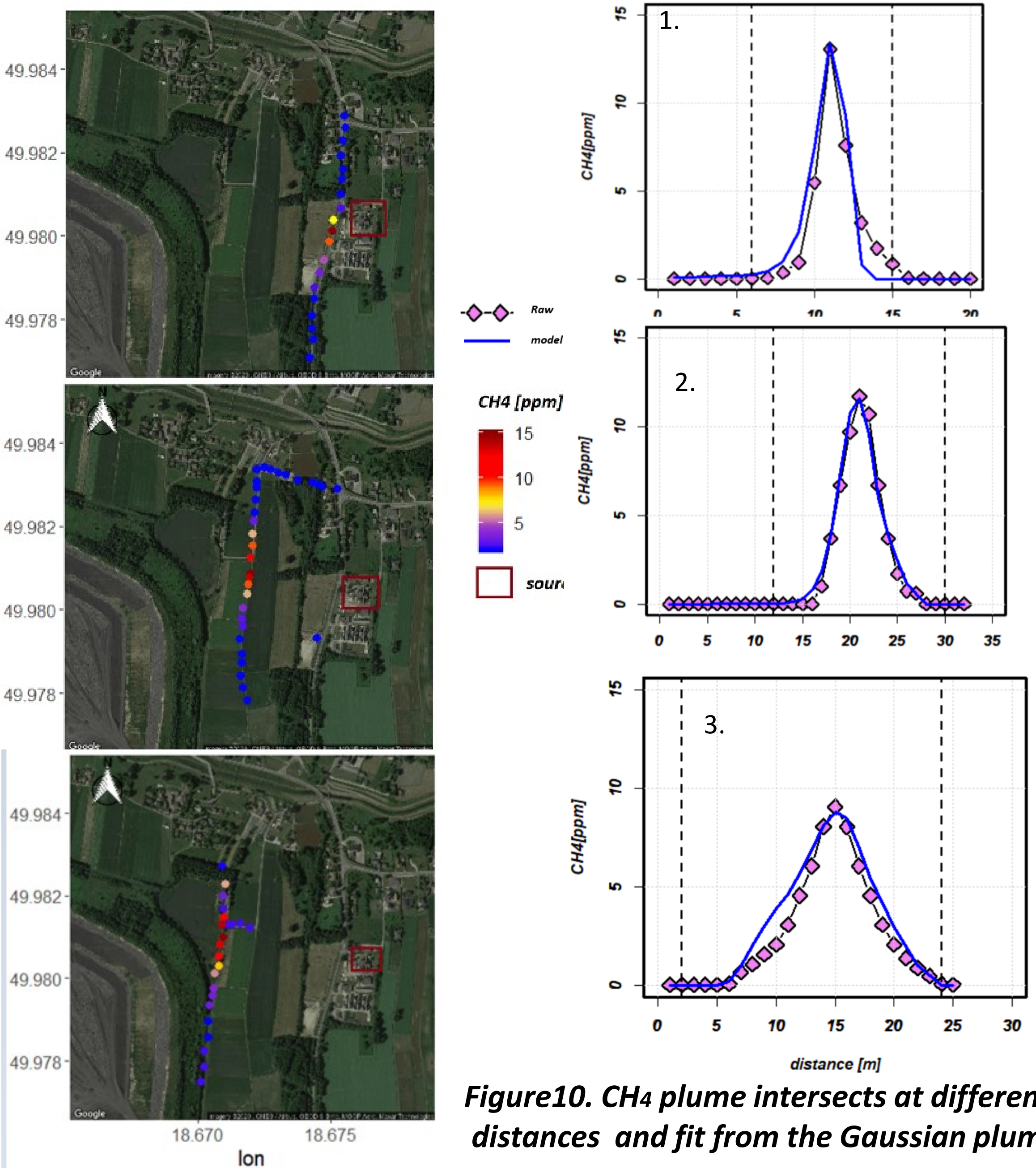
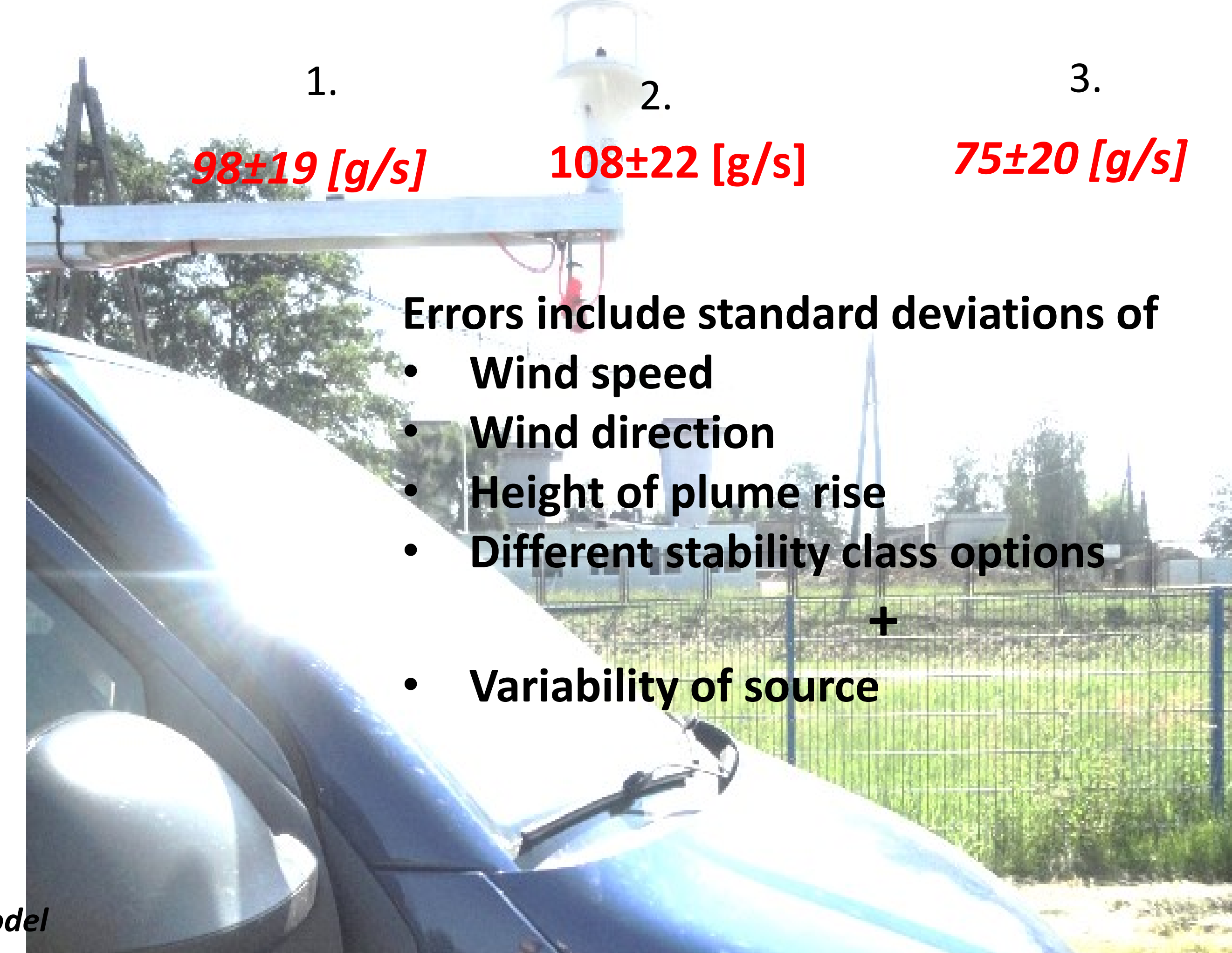


Figure10. CH4 plume intersects at different distances and fit from the Gaussian plume model



3 transect at the same ventilation shaft on the same day: 1.6.2018

Estimated emissions:

1.	2.	3.
98±19 [g/s]	108±22 [g/s]	75±20 [g/s]

Errors include standard deviations of
- Wind speed
- Wind direction
- Height of plume rise
- Different stability class options

+

- Variability of source

Results: what happens when wind information changes (sensitivity test)

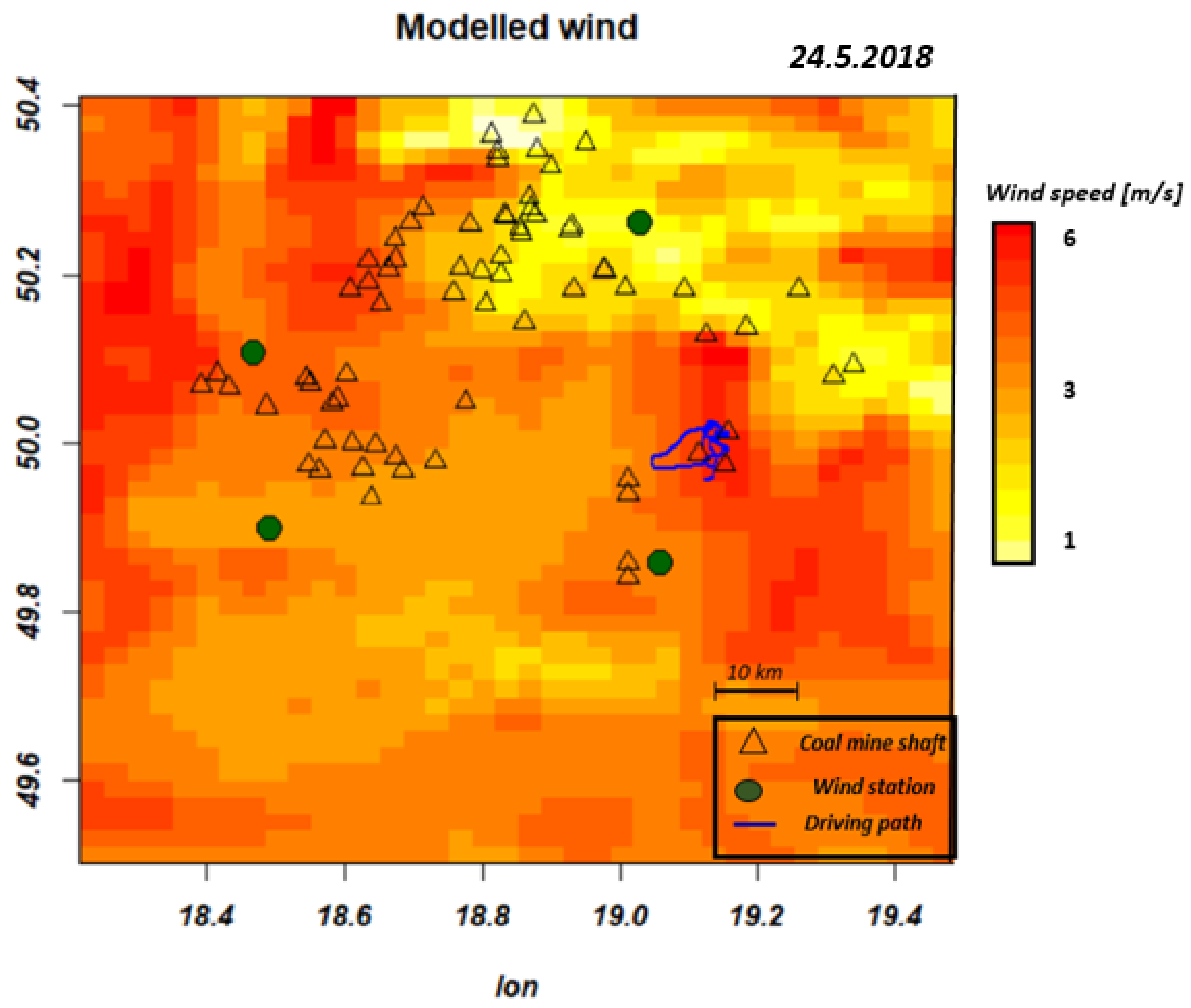


Figure 11. Spatial distribution of wind speed across Silesia. Plot demonstrates that wind stations are far from measurements (even more than 10km)

The wind information is from:

1. **4 wind station across the USCB**
   The nearest station is 10km far from measurements

1. **WRF-GHG simulations: 2x2 km gridded area (wind information nearly source)**

Results: what happens when wind information changes

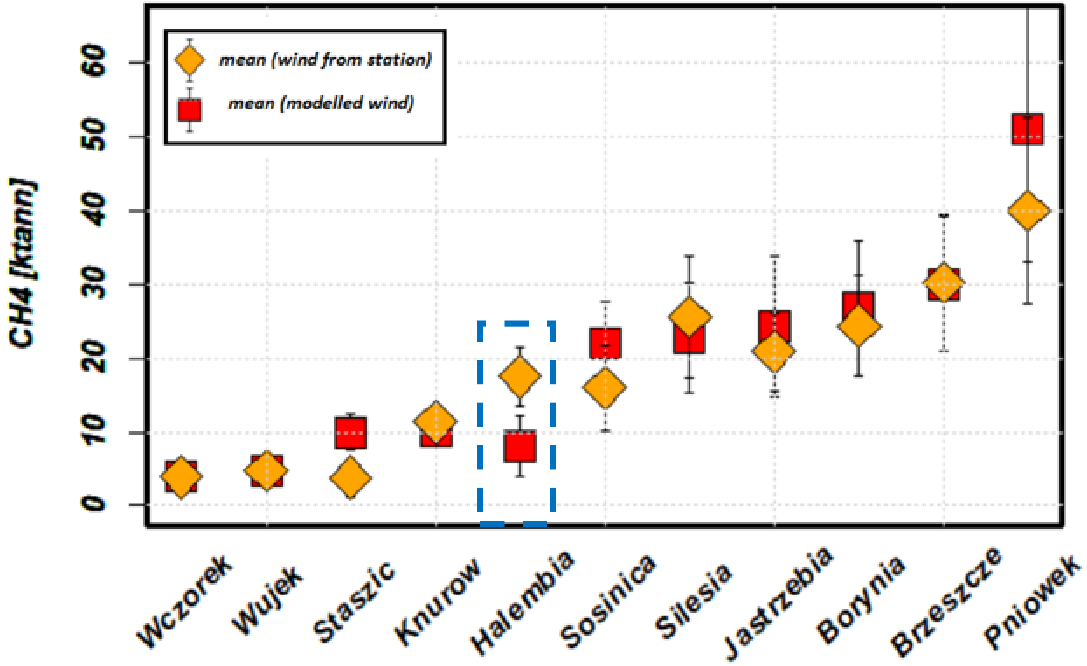


Figure 12. Summary of results for particular mining facility; the dashed blue line indicates the highest difference between results

- ***CH_4 emission calculated with wind information from the nearest wind station and from the WRF-GHG model simulation***

- ***In particular mining facilities (figure 12; dashed blue line) , changes in the wind speed leads to difference up to 50%***

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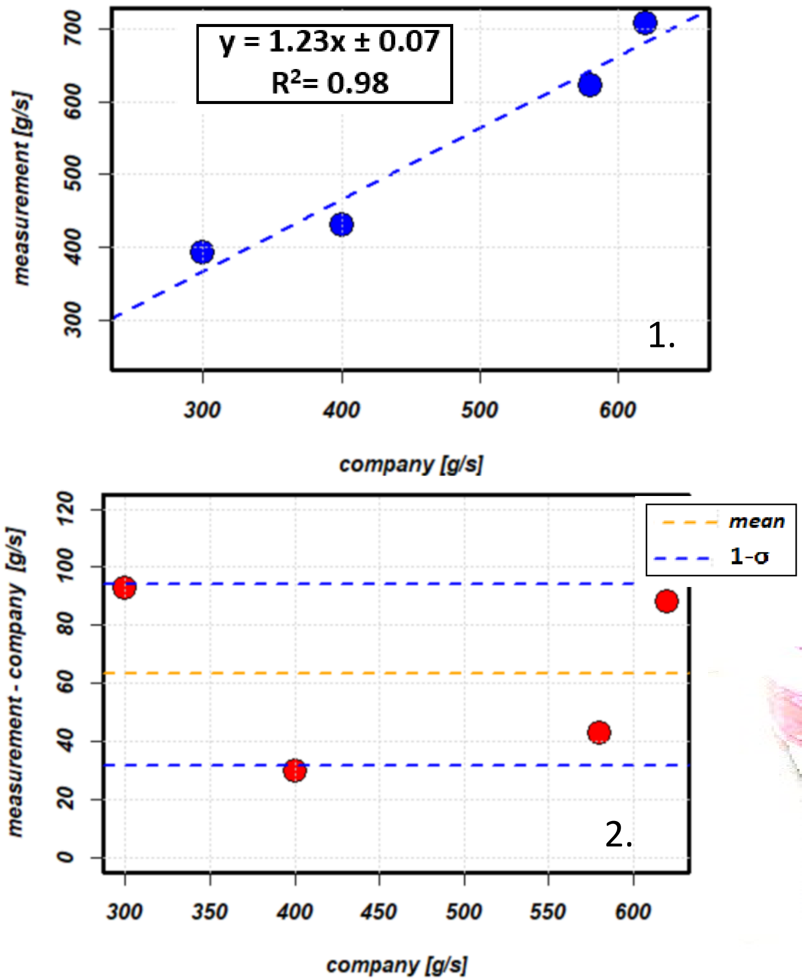
Comparison: our CH_4 estimates with estimates from mining companies



Comparison: how much CH_4 emissions estimates with our methodology differ from those of mining companies estimates

The results (Figure 13) shows:

- Excellent agreement (less than 10% of the difference); figure 12. 1)
- The difference between our and companies estimations are in 2σ range :± 40 [g/s] (figure 13)

Figure 13 . Comparison: our estimates and mining companies estimates
1)Correlation plot our measurements versus the CH_4 estimates by the company
2)difference plot: difference between our and company estimations versus the company estimations

Results: Comparison with E-PRTR database

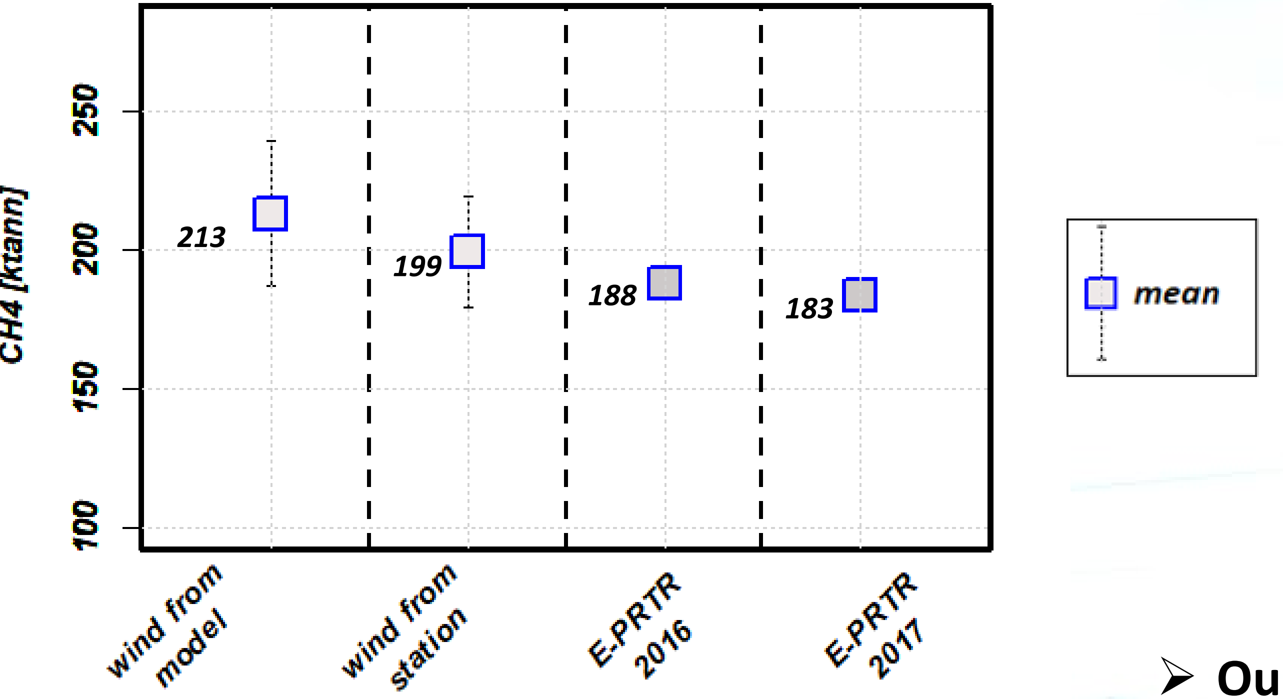


Figure 13. Results compared with E-PRTR database

Table1. Summary of results

Type of results	CH_4 [ktann]
Wind from model	213±53
Wind from station	199±40
E-PRTR 2016	188
E-PRTR 2017	183

- **Our results compared with E-PRTR database reports**

- **However E-PRTR database:**
  - **Does not contain data for 2018 (year of our measurements)**
  - **The database is without uncertainty**

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Methane isotopic signature: Keeling approach

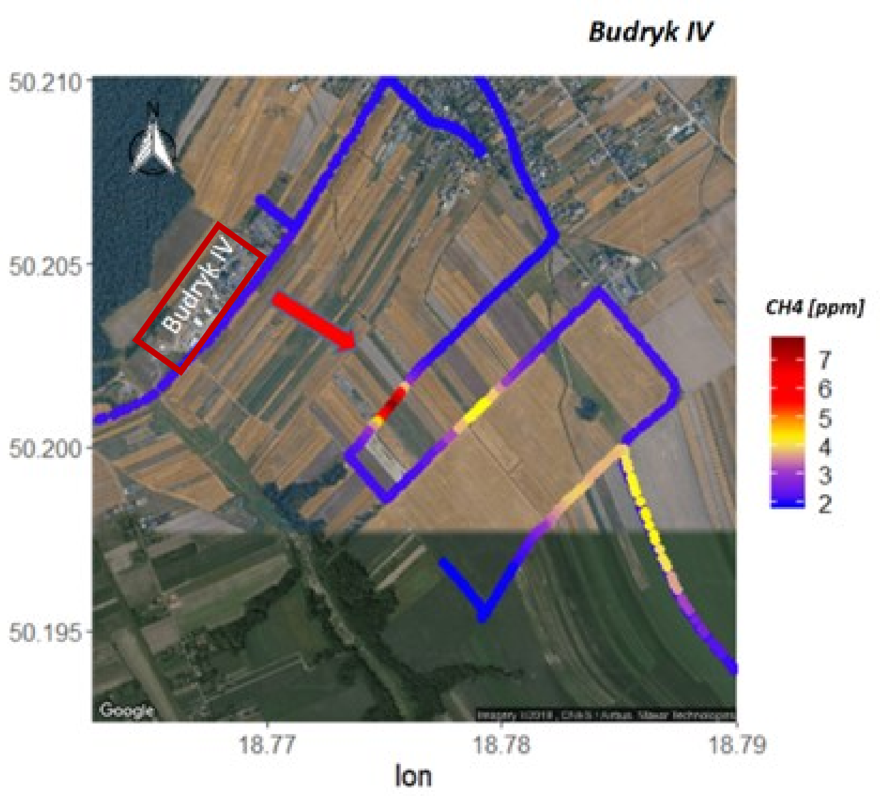
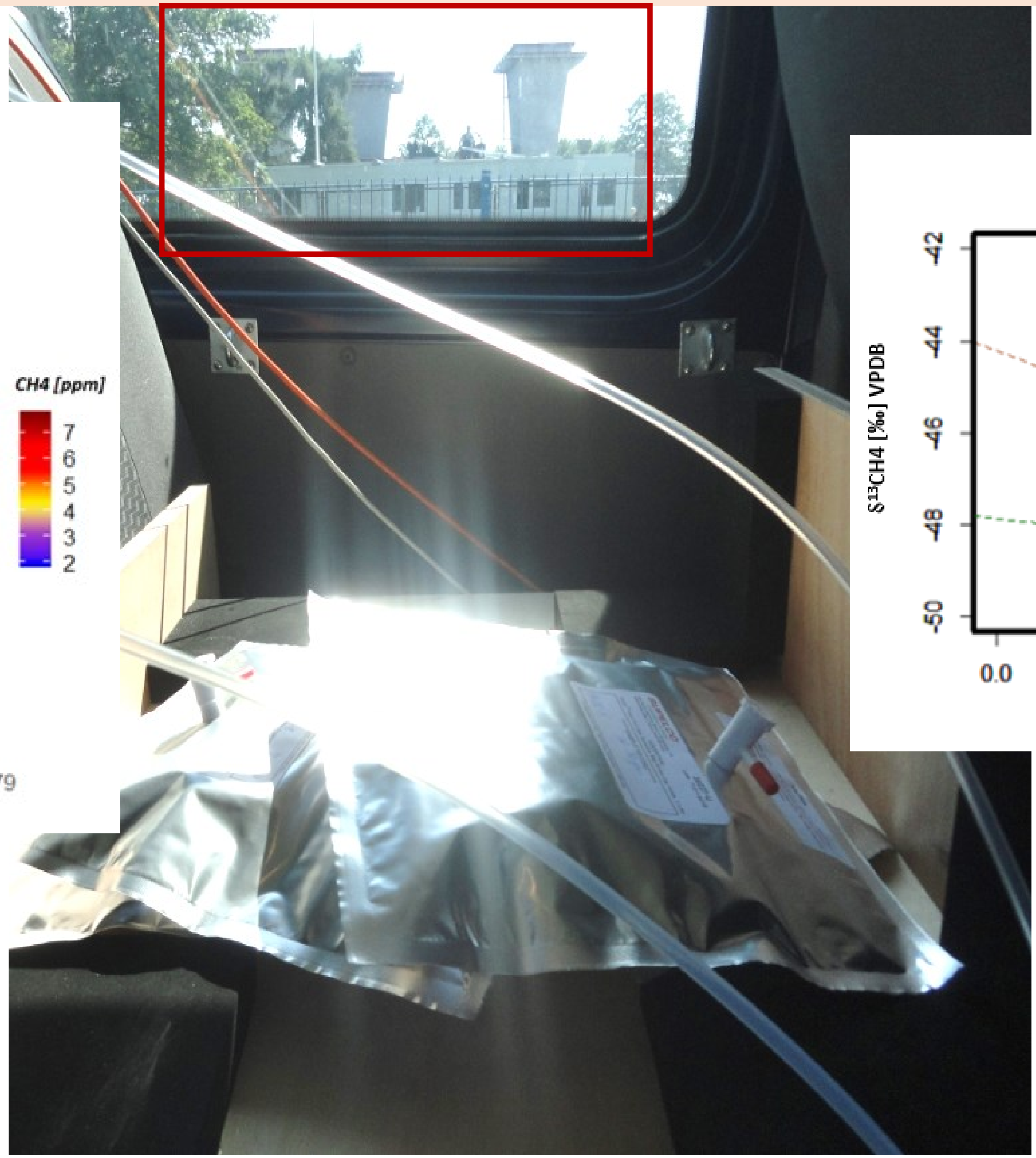


Figure 14. Collection of bag samples during plume transects at different distances



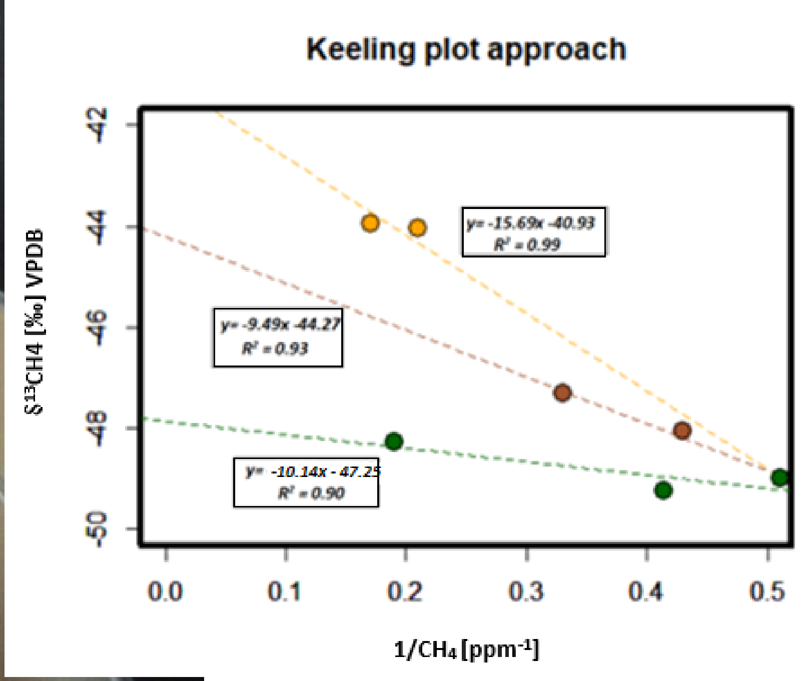


Figure 15. Keeling plot approach. Determination of CH_4 isotopic signature

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Methane isotopic signature: origin of gases

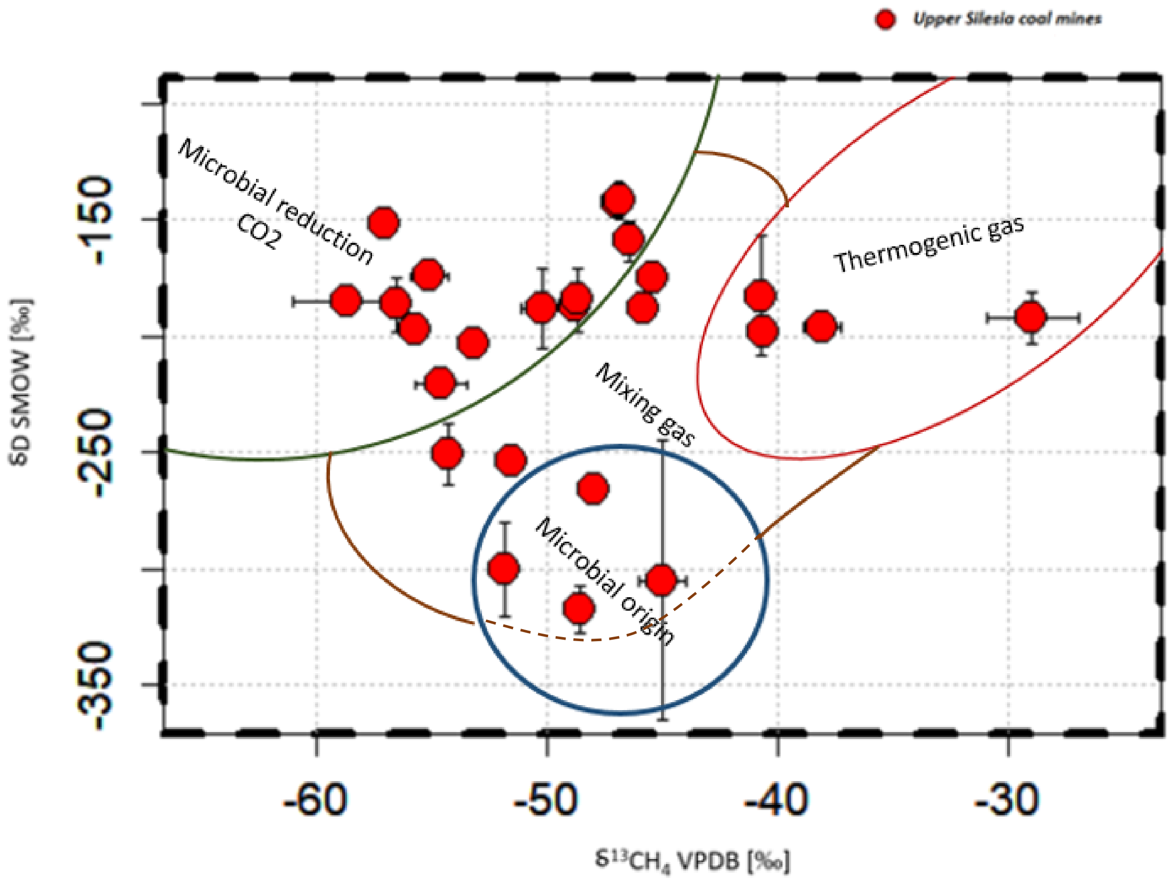

Figure 16. CH_4 isotopic composition and origin of gases

CH_4 isotopic signature from coal ventilation shafts:

In total 70 bag samples were collected;
24 different coal ventilation shafts were isotopically characterised

Results indicates different origin of gases:

- ***Thermogenic gas***
- ***Microbial gas***
- ***Mixing gas***

Results: methane isotopic signature

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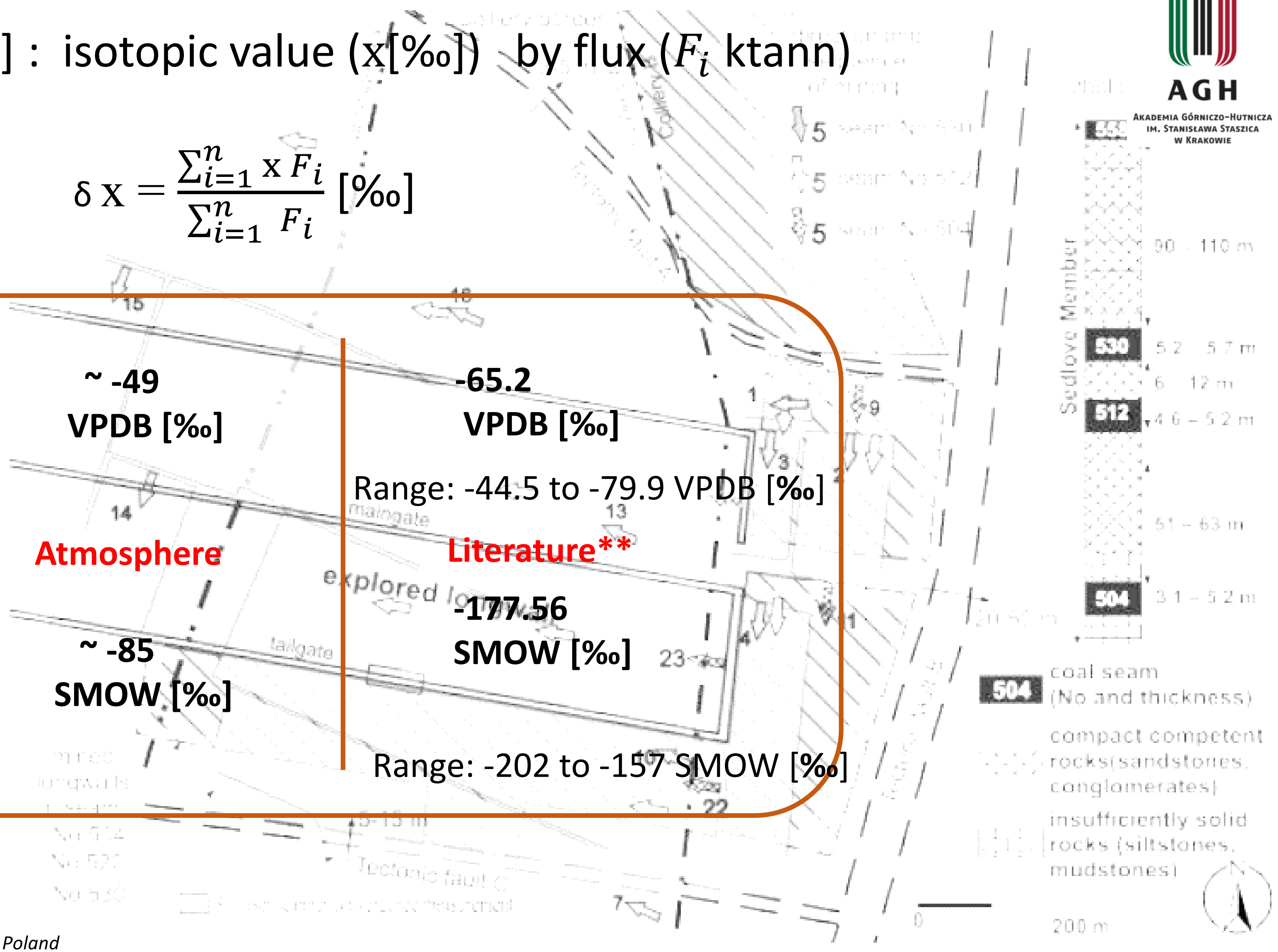
Weight average δ x [‰] : isotopic value (x[‰]) by flux (F_i ktann)

$$\delta\, x = \frac{\sum_{i=1}^{n} x\, F_i}{\sum_{i=1}^{n} F_i}\ [‰]$$

n= 24



Upper Silesia	Atmosphere	Literature**
$\delta^{13}CH_4$: **-49.9 VPDB [‰]**	**~ -49 VPDB [‰]**	**-65.2 VPDB [‰]**
Range: -28 to -58 VPDB [‰]		Range: -44.5 to -79.9 VPDB [‰]
δ **D : -236.5 SMOW [‰]**	**~ -85 SMOW [‰]**	**-177.56 SMOW [‰]**
Range: -321 to -142 SMOW [‰]		Range: -202 to -157 SMOW [‰]

**Kotarba et al, 2001;
Composition and origin of coalbed gases in the Upper Silesian and Lublin basins, Poland

Summary:

- Calculated CH_4 fluxes compared with E-PRTR database report
- Our methodology is sensitive to wind estimates
- Isotopic signatures indicate different origin of gases
- Weighted average CH_4 isotopic signature for USCB determined from different ventilation shafts

Further project partners: National Physical Laboratories (GB), SHELL (NL), Isoprime (GB), OonKAY (NL), Afvalzorg Deponie (NL), Viridor (GB), Whiffle Weather Finecasting (NL)

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