Plume quantification for
Remote sensing enables basin-scale inventories of coal mine methane

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We adapt the approach used for quantifying EMIT plumes in Ayasee et al.[1] for aircraft plumes. We select plume pixels following the plume segmentation algorithm in the Carbon Mapper Algorithm Theoretical Basis Document v1.0.0[2], and calculate the integrated mass enhancement (IME) of each plume. The emission rate at the source is calculated by multiplying the IME by the lifetime of methane in the plume mask, expressed as windspeed (U) over plume length (L):

$$Q = \mathrm{IME}\frac{U}{L}$$

Where U is 10 m windspeed from HRRR. We find the length of the plume by taking the distance from the plume origin to the farthest edge of the plume. We estimate quantification errors as follows:

$$\sigma Q = Q\sqrt{\left(\frac{\sigma U}{U}\right)^2 + \left(\frac{\sigma \alpha}{\alpha}\right)^2}, \qquad \alpha = \frac{\mathrm{IME}}{L}$$

where σU is the uncertainty of the HRRR windspeed, calculated using the standard deviation of wind speeds in a 9km window over 3 hours. To estimate uncertainty on α we start at the origin of the plume successively increase the radius r until we reach L, and take $\frac{\mathrm{IME}}{r}$ at each step, filtering out slices above the 95th percentile to avoid a bias from vertical convection near the origin of the plume. We take the standard deviation of these slices to find $\sigma\alpha$.

References

1. Ayasse, A. K. *et al.* Probability of Detection and Multi-Sensor Persistence of Methane Emissions from Coincident Airborne and Satellite Observations. *Environ. Sci. Technol.* **58**, 21536–21544 (2024).
2. Carbon Mapper, Inc. Algorithm Theoretical Basis Document: L3/L4: Methane and Carbon Dioxide Emission Quantification for Satellites v1.0.0. (2024).