

# Global Methane Budget and Natural Gas Leakage Based on Long-term $\delta^{13}\text{CH}_4$ Measurements and Updated Isotopic Source Signatures

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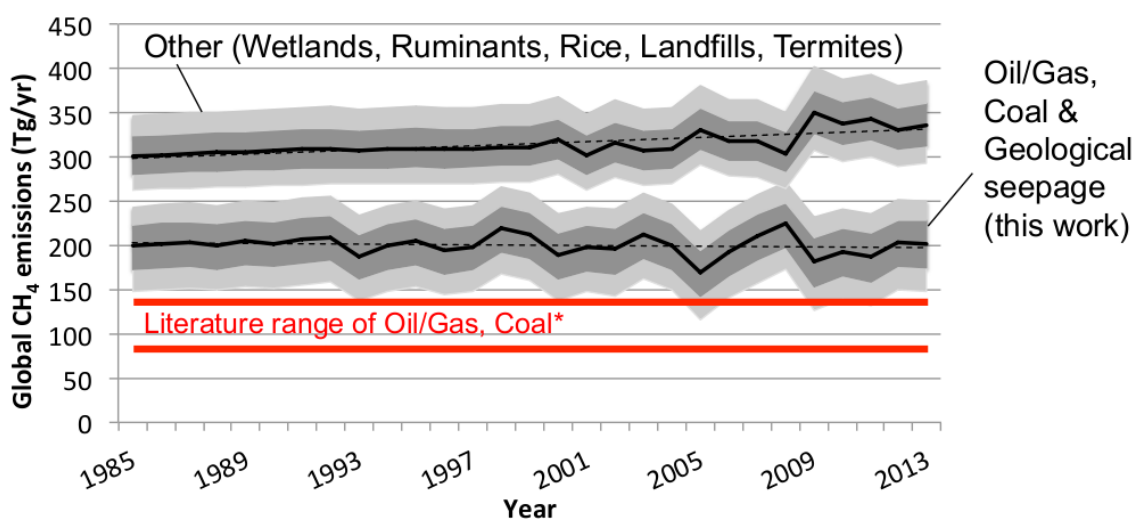
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Recent field studies in the U.S. indicate that emissions inventories developed and used by regulatory agencies may significantly underestimate methane ( $\text{CH}_4$ ) emissions associated with extraction and use of fossil fuels (natural gas, oil, and coal). We use atmospheric measurements from NOAA's Global Greenhouse Gas Reference Network spanning the past three decades to estimate global  $\text{CH}_4$  emissions from fossil fuels and other sources and compare these with inventories and inversion studies. Atmospheric measurements include globally averaged  $\text{CH}_4$  and stable isotopes ( $^{13}\text{CH}_4$ ), which are used in a global box-model to constrain source magnitudes. To calculate uncertainties, probability distribution functions of the key atmospheric model parameters are derived. Isotopic source signature distributions are based on the largest literature survey to date, which suggests significant corrections compared to previous studies. Then, a Monte Carlo simulation of the box-model calculation is performed to quantify confidence intervals of individual emissions sources. Attributing the majority of increased  $\text{CH}_4$  levels over the past three decades to microbial sources is consistent with  $^{13}\text{CH}_4$  records. The sum of  $\text{CH}_4$  emissions from fossil fuel extraction and usage and geological seepage is significantly larger than previous estimates. Finally, recently published estimates of global  $\text{CH}_4$  emissions from oil and coal production and usage are subtracted from our global fossil fuel  $\text{CH}_4$  results to quantify global  $\text{CH}_4$  leakage from the natural gas industry during extraction, processing, transport, and distribution of the fuel. Natural gas  $\text{CH}_4$  leakage as a fraction of total production has decreased steadily over the same period indicating industry efficiency improvements.



\* Most top-down studies exclude geolog. seepage. Note: Biomass burn. not shown (30-60 Tg/yr)

**Figure 1.** Preliminary top-down modeling results using updated  $\delta^{13}\text{C}$  source signatures from the literature. Black solid lines represent median values for the respective emissions categories (dashed lines show long-term trend), and light and dark gray bands indicate uncertainties (10th/90th and 25th/75th percentiles, respectively).