Increasing Natural Gas Demand Threatens China's Carbon Reduction

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Background Atmospheric methane emissions underestimated

- Estimates of methane emissions from oil and gas are underestimated.

Natural gas leaks are the largest anthropogenic source of the greenhouse gas methane (CH_4) in the U.S.

The national methane leakage from pipeline mains estimate is approximately 5 times~ greater than the U.S. EPA's current greenhouse gas inventory (Weller et al., Environ. Sci. Technol. 2020, 54, 8958−8967)
Eight-year estimates of methane emissions from oil and gas operations in western Canada are nearly twice those reported in inventories. (Chan et al., Environ. Sci. Technol. 2020, 54, 14899−14909)

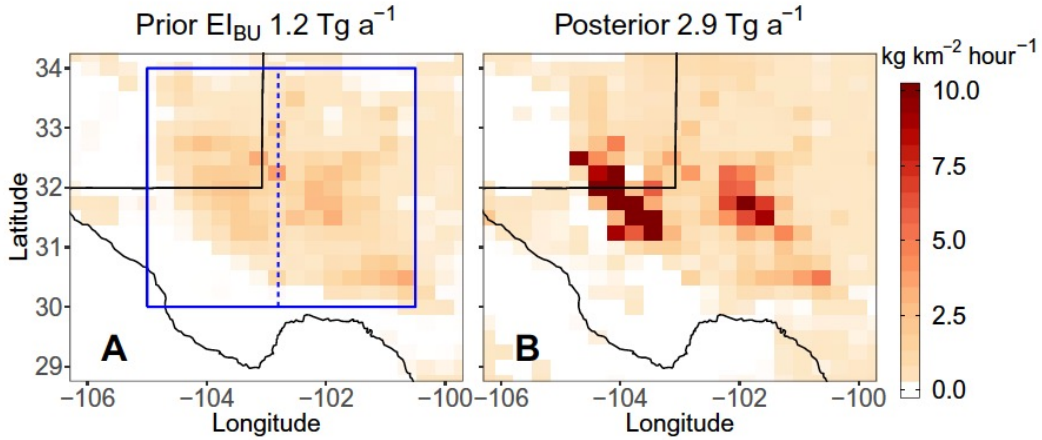
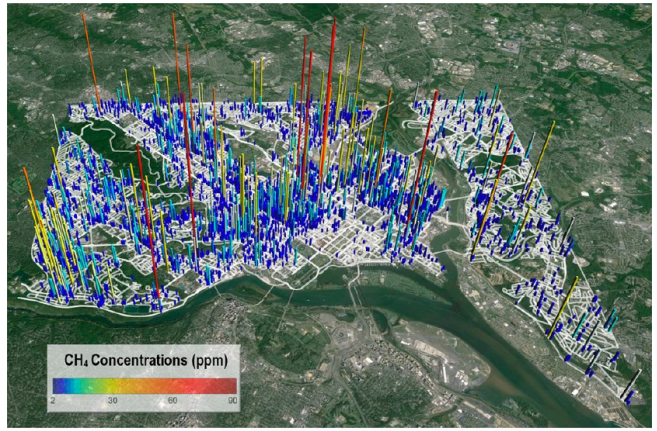


Fig. 5. Spatial distribution of methane emission rates in the Permian Basin.

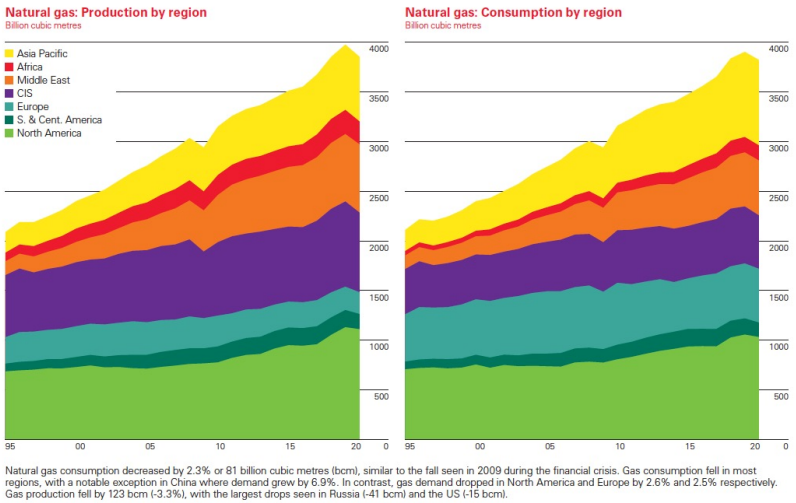
This magnitude of emissions is 3.7% of the gross gas extracted in the Permian, i.e., ~60% higher than the national average leakage rate. (Zhang et al., Sci. Adv. 2020; 6 : 5120)



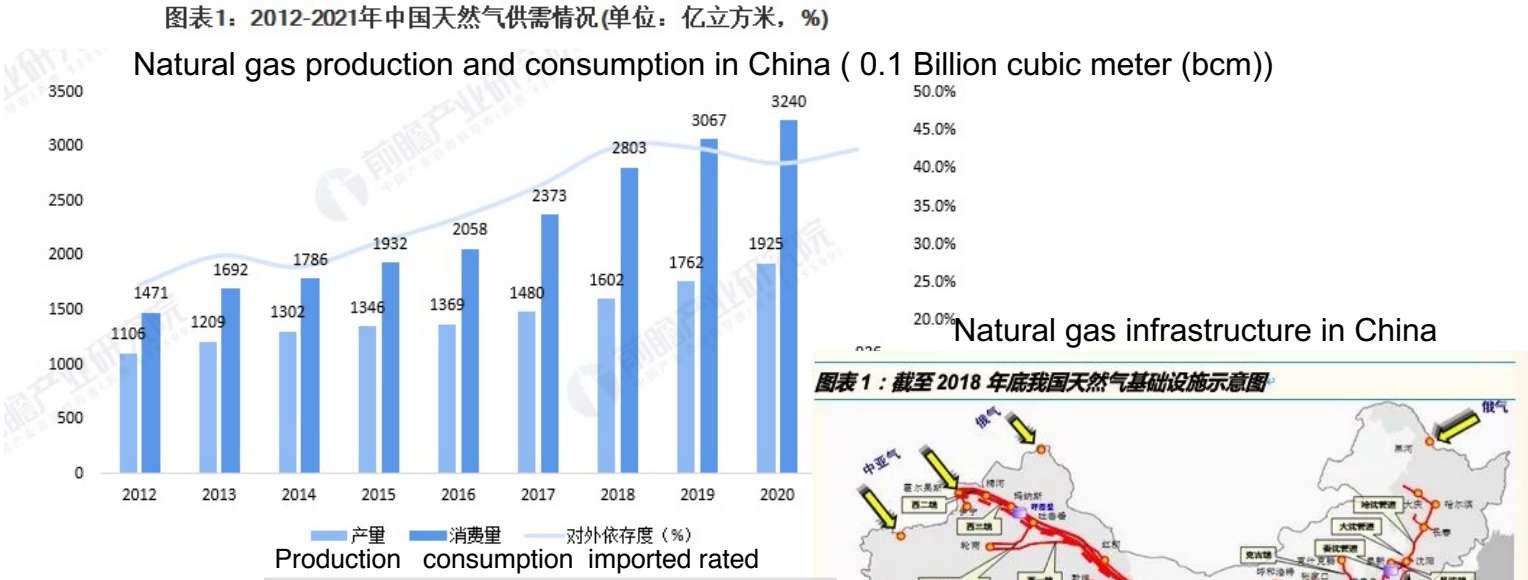
Mapping urban pipeline leaks: Methane leaks across Boston (Jackson, et al., Environ. Sci. Technol. 2014, 48, 2051−2058)

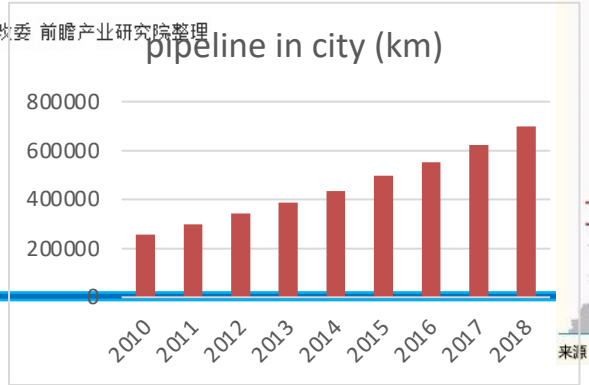
Background Atmospheric methane emissions underestimated

- Global production and consumption of natural gas (NG) (70%-90% methane) keep increasing, almost doubled in the last 15 years. The increase in China is dramatic since 2012, along with coal-to-gas strategy to reduce air pollution.



(bp Statistical Review of World Energy 2021)





Natural gas infrastructure in China

NIES
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Methods Inverse model setup

NTFVAR, coupled Eulerian-Lagrangian transport model (NIES-TM resolution 2.5° × 2.5° + FLEXPART model resolution 0.1° × 0.1°) (Maksyutov et al., *Atmos. Chem. Phys.*, 2021)

- Prior fluxes, sinks:

1) Anthropogenic emissions (EDGAR v5).
2) Biospheric emissions (VISIT)
3) Biomass burning (GFASv1.2) (daily)
4) Termites, ocean, geological as in Transcom-CH_4
5) 3D monthly OH, O1D, Cl as in Transcom-CH_4

- Prior uncertainty:

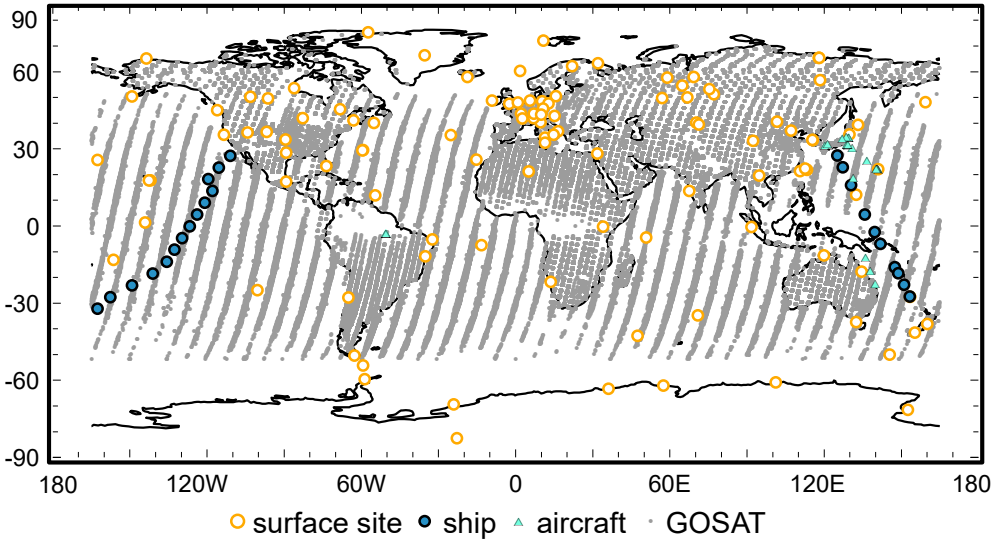
anthropogenic: monthly EDGAR (multiplied by 0.3)

natural: VISIT wetland emissions (multiplied by 0.5)

- Inversion period: 2010 – 2018

- Observations:

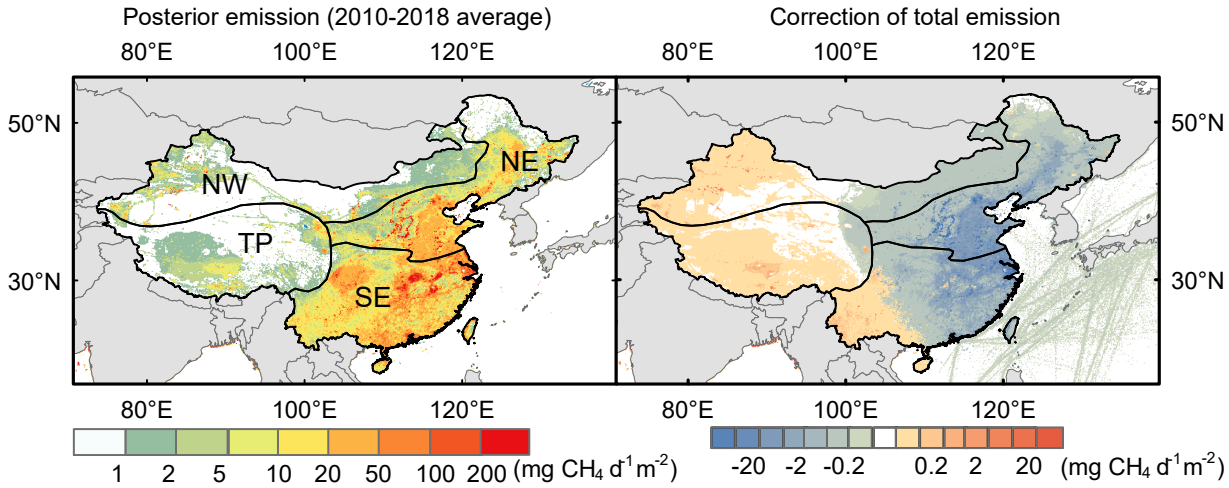
1) GOSAT GOSAT retrievals (NIES, Level 2 retrievals, v. 02.81)
2) Ground CH_4 observations from WDCGG, surface sites, aircraft and ship observations.



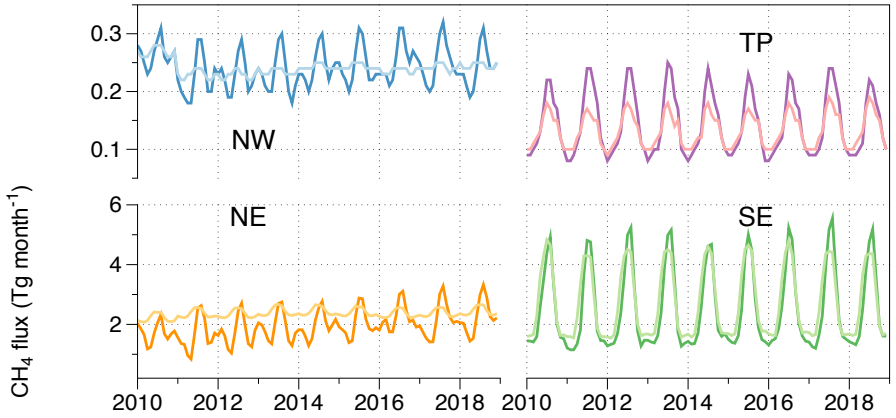
(Wang et al., *Scientific Reports, 2022, Accepted*)

Results Inverse estimation

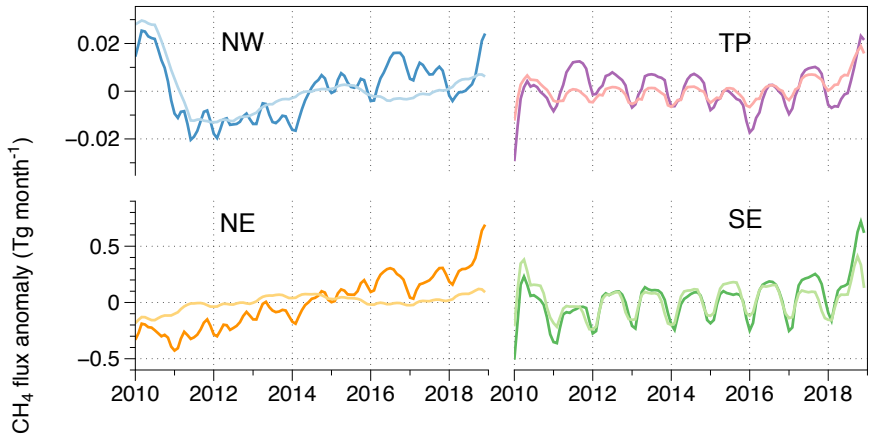
- Inverse corrections are downwards in the east and upwards in the west.
- The seasonal variabilities in TP and SE with maximum emissions in summer and minimum in winter correspond to wetlands and rice paddy.
- Statistically significant increase trends in 2010-2018 are detected in NE for both prior and posterior flux anomalies of total CH_4 emissions
- Ton km2/year .



The seasonal variations of prior (lighter) and posterior (darker)



The annual anomalies



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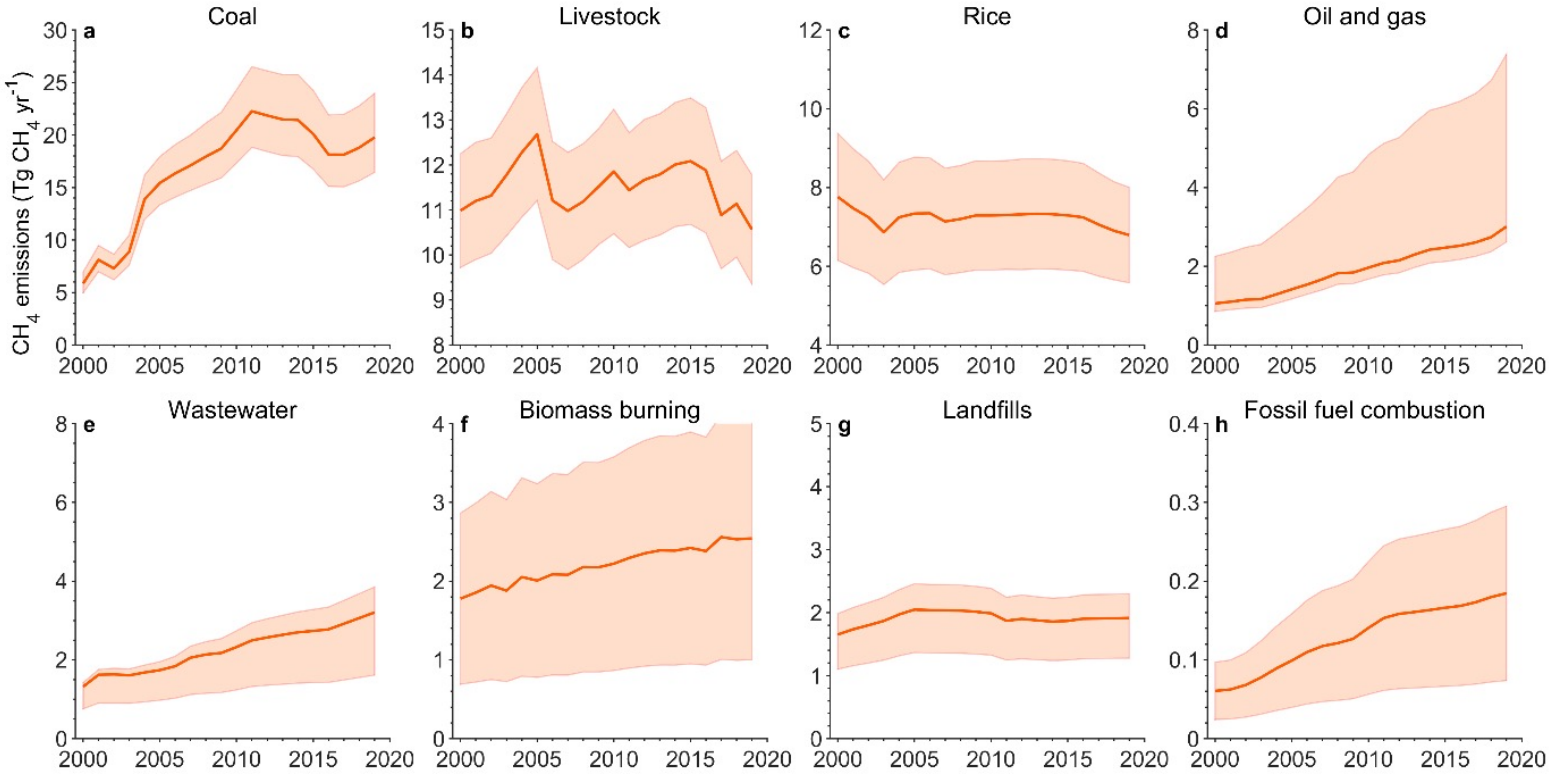
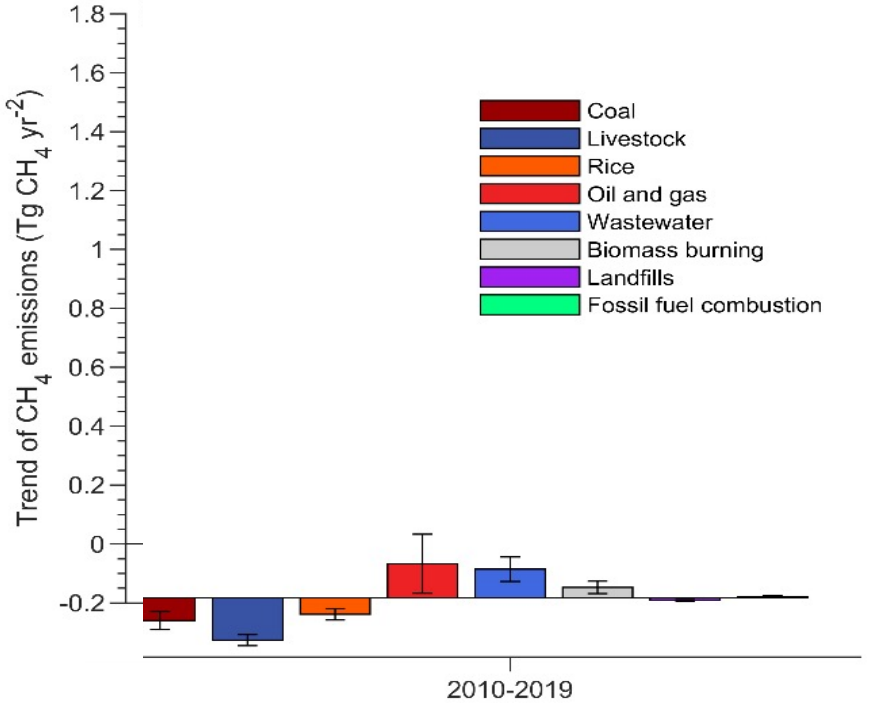
Results Bottom-up emission estimate

CH_4 emissions from different source sectors during 2000-2019 in China



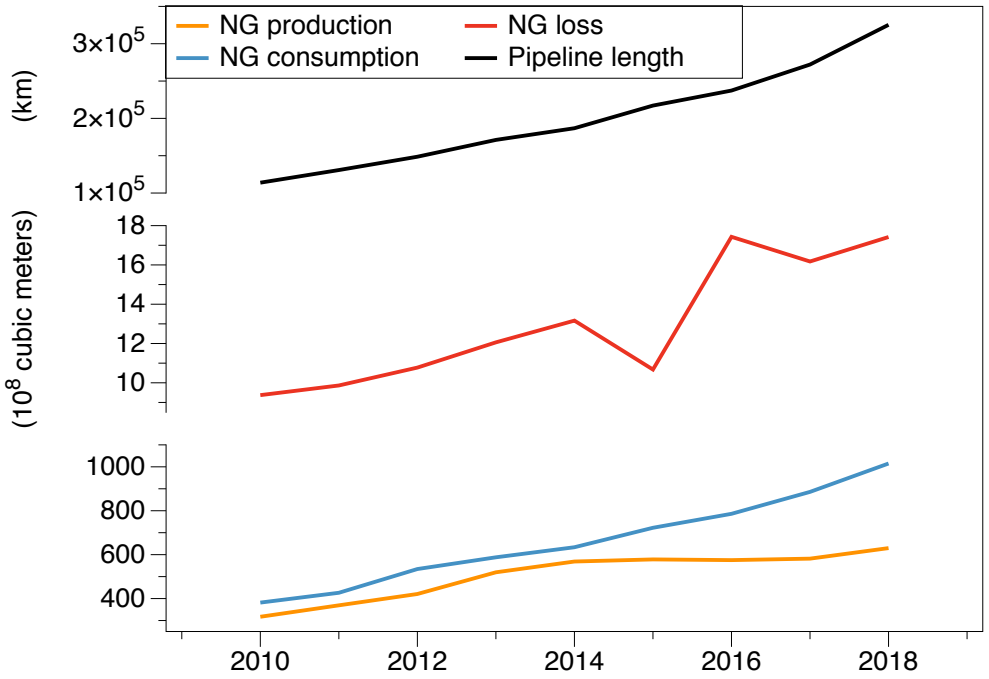
The trends in sectoral anthropogenic emissions during 2010-2019 in China



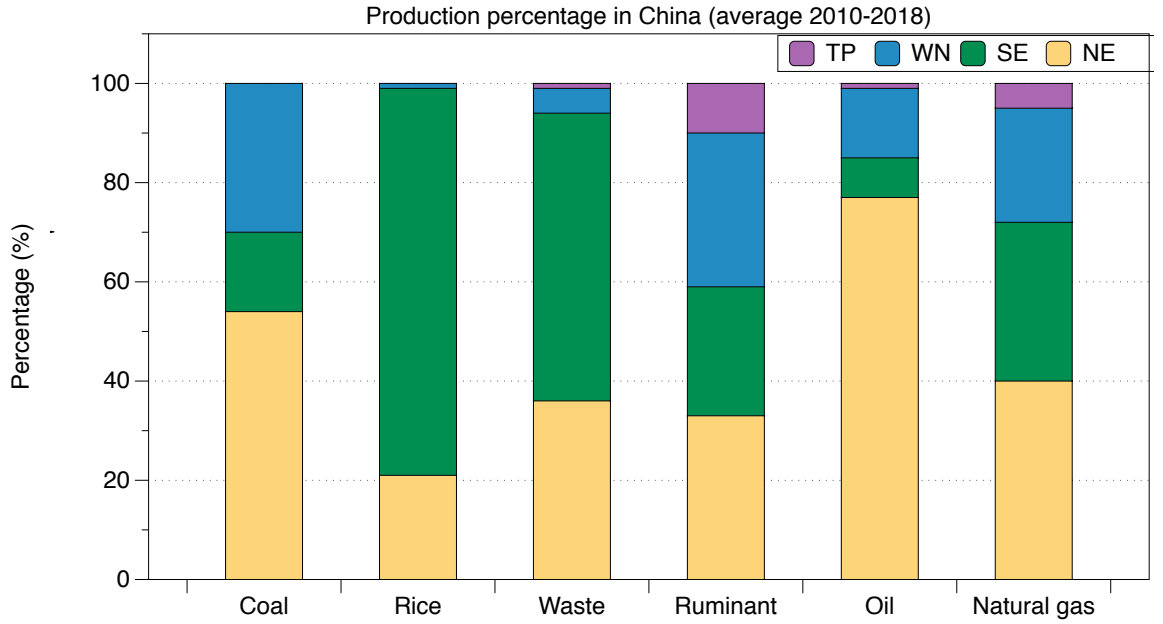
(Liu et al., Environ. Sci. Technol. Lett. 2021, 8, 9, 739–746)

Results Bottom-up emission estimate

Length of the pipeline, natural gas production, consumption, and loss in North-East China from 2010-2018



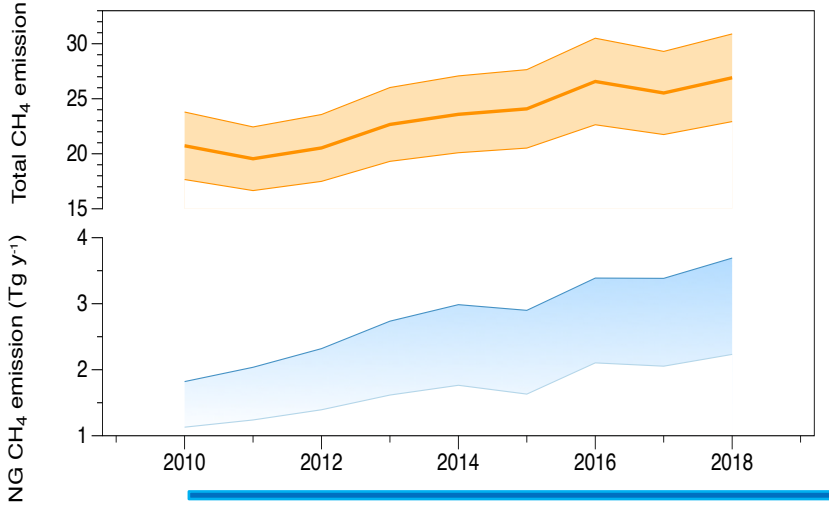
Sectional production (2010-2018) in four regions of China



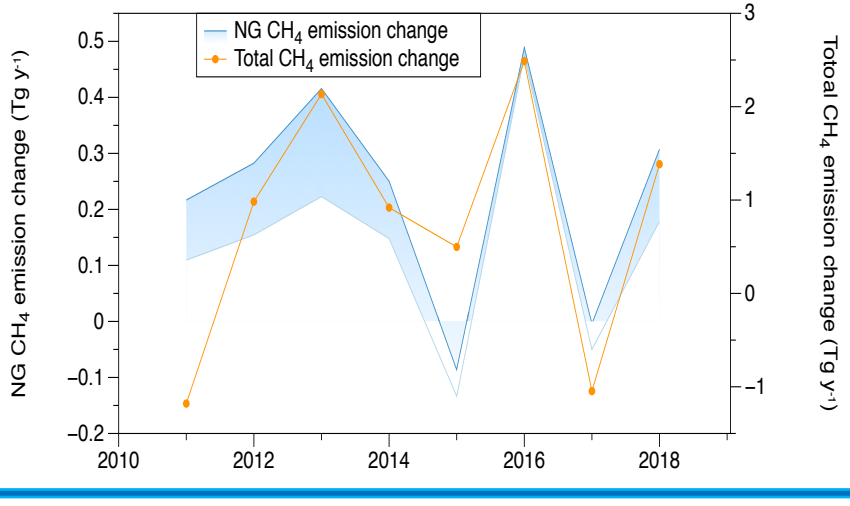
Results Trend in posterior follows natural gas emission in North-East China

- The estimated CH_4 emissions from natural gas and the total posterior CH_4 emissions in North-East of China show statistically significant increasing trends.
- The variation of total CH_4 emission increase closely follows the changes in CH_4 emissions from natural gas.
- Taking 2018 year as an example, in the NE region the NG production is 63 bcm, and the NG consumption is 101.5 bcm. The estimated total natural gas emission is 3.2~5.3% of the regional natural gas consumption.

Estimated CH_4 emissions from natural gas and total CH_4 emissions



CH_4 emission increment relative to previous year



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Summary

- With a high-resolution (0.1°× 0.1°) inverse model, we analyze the regional CH_4 emissions in China.
- Results highlight the relevance of natural gas use and pipeline expansion to methane emissions in the North-East China.
- The increase of leaking methane from natural gas production and use chain will cause potential danger to diverse stakeholders despite introducing a net carbon reduction.
- Given the large natural gas distribution pipelines 935.6 million meters in China, natural gas leakage can be a significant waste of energy and money. It can also accelerate ozone formation in urban areas.
- GOSAT observation is coarse to capture natural gas leakage, and city-scale mobile surveys, facility-level measurements are suggested to further investigate natural gas emissions in China.
- Advanced leak reduction technologies in the natural gas end-use sector can also bring economic, environmental, and health benefits.

Thank you