CH_4 emissions estimates and sensitivity analysis using STILT-inversion over South Korea (2010-2021)

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Introduction

✓South Korea aims to reduce GHGs by 2030 and reach carbon neutrality by 2050, but methane emission uncertainties remain. This study uses Bayesian inversion with the STILT model to derive top-down CH_4 estimates (2010–2021). Results highlight gaps in bottom-up inventories.

Data and method

Category	Data source
Coal, Agriculture, Waste, Biofuels, Oil,Gas & Industry	EDGAR v7.0 EDGAR v6.0 (for monthly scale factor)
Fire	GFAS
Wetland, Soi sink	VISITv20230209b
Termites	Saunois, 2022
Ocean	Saunois, 2022
Geological	Saunois, 2022
Freshwater	Saunois, 2022

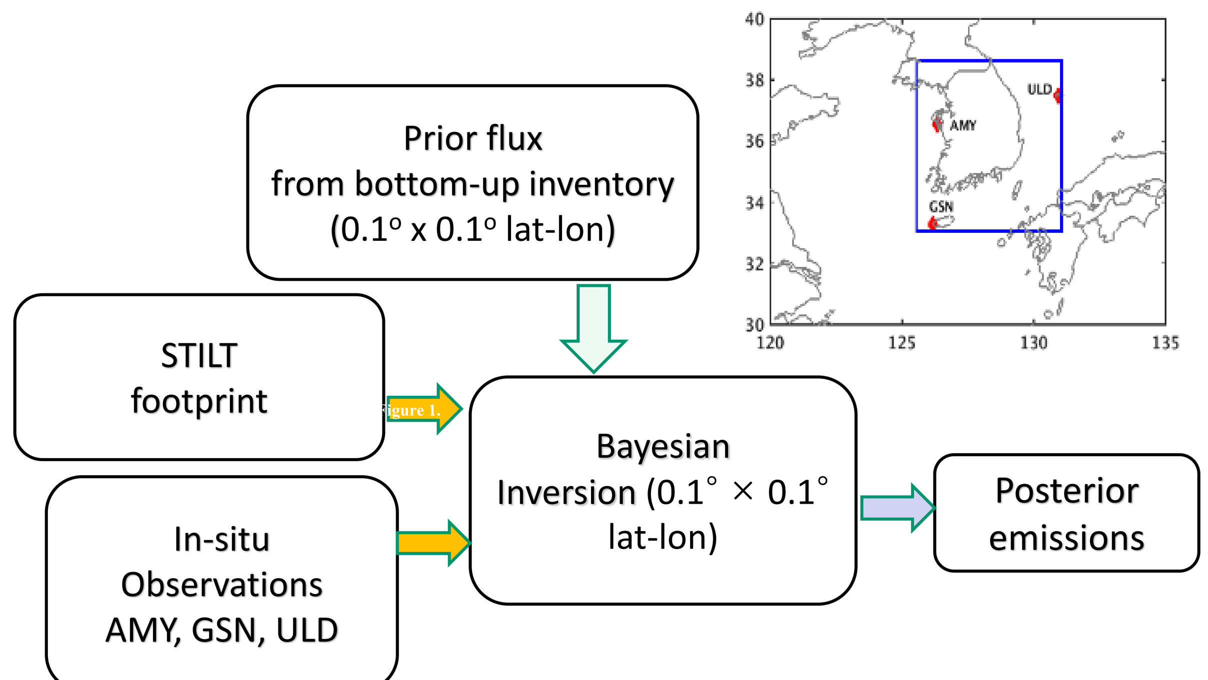

Fig. 1

Inversion systems

▪STILT-Inversion (NIMS) - Exp 1: Surface CH_4 observations

▪FLEXPART - NIES: Exp 1: Surface CH_4 observations; Exp 2: GOSAT XCH_4 retrievals; Exp 3: GOSAT+Surface observations

Results

➢Annual posterior emissions and inter-comparisons

• Posterior emissions are lower than prior estimates obtained by the inversions (Fig.2).

• Largest reductions occurred in urban areas such as Seoul (Fig.3, shown by STILT exp1)

• Bottom-up inventory overestimated CH_4 emissions.

• Posterior estimates are lower than priors, 3.2%–9.3% (STILT), 0.8%–12.5% for FLEXPART exp1

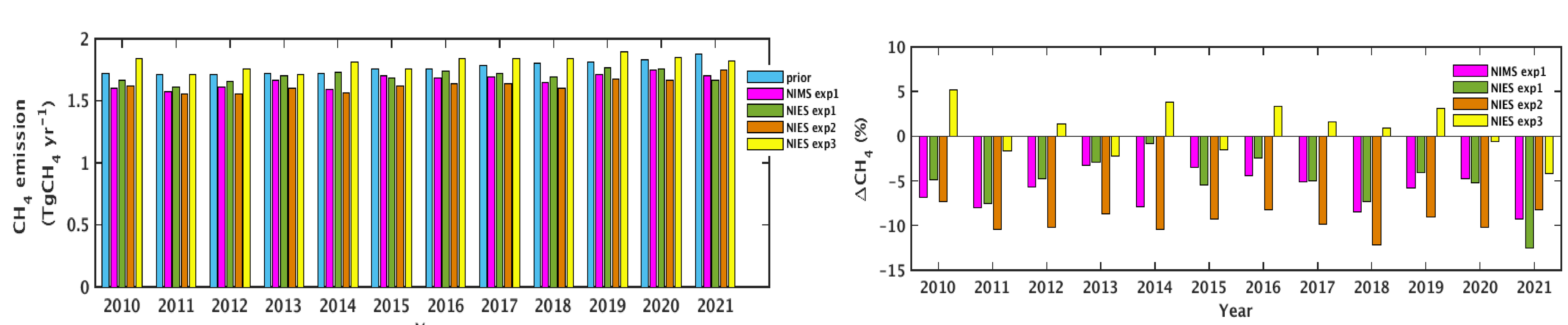

Fig. 2

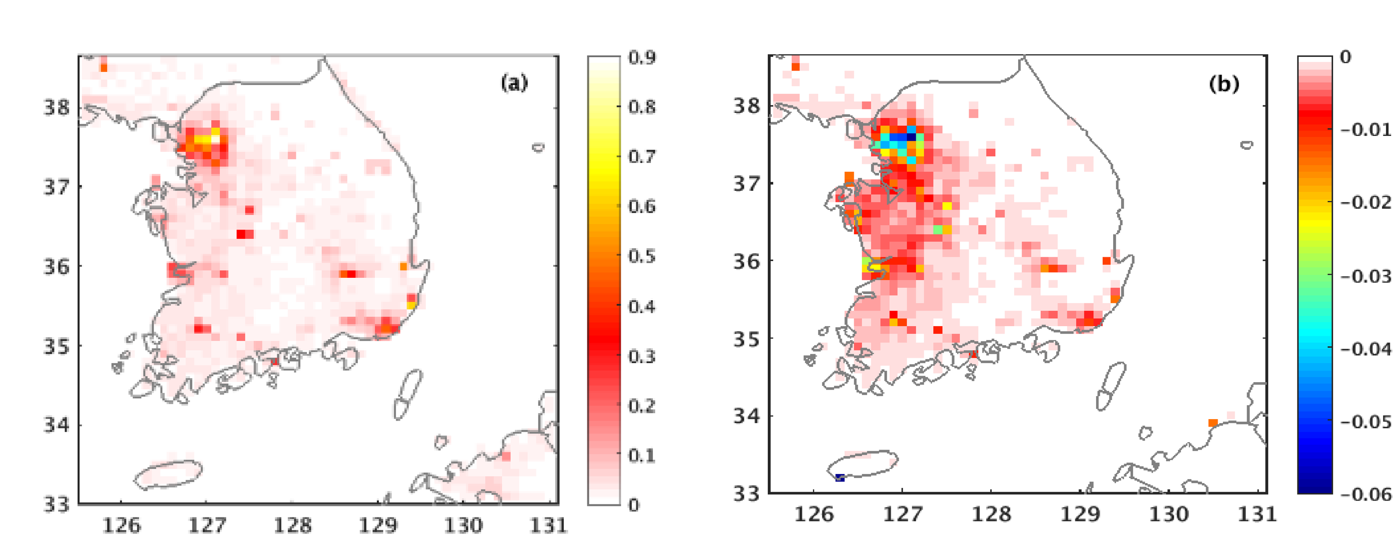

Figure 3. A 12-year mean posterior (a), posterior minus prior (b), CH_4 emissions for 2010-2021.

➢ Seasonal cycle in CH_4 emission adjustments

- Pronounced seasonal cycle driven by agriculture and waste sectors.
- Posterior emissions peak in July; spring onset delayed the minimum, unlike January minimum in prior.
- Spring shows largest correction (−18.2 Gg/month), winter the smallest.

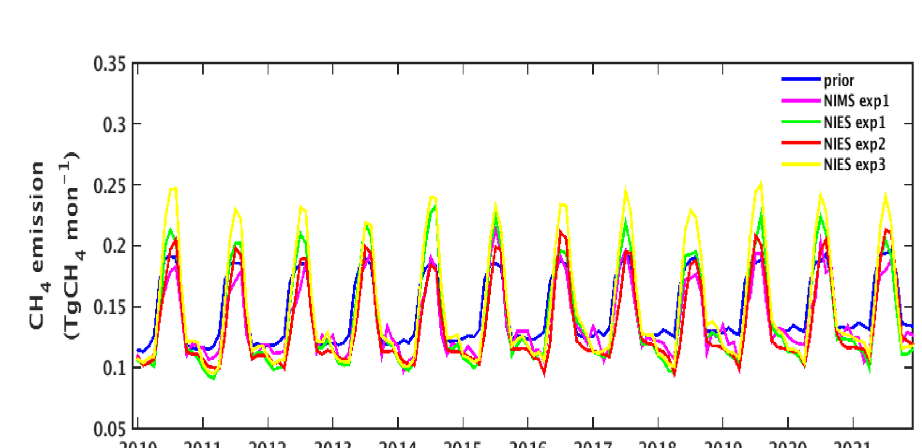

Fig. 4

➢Simulated CH_4 mole fractions from inverse model

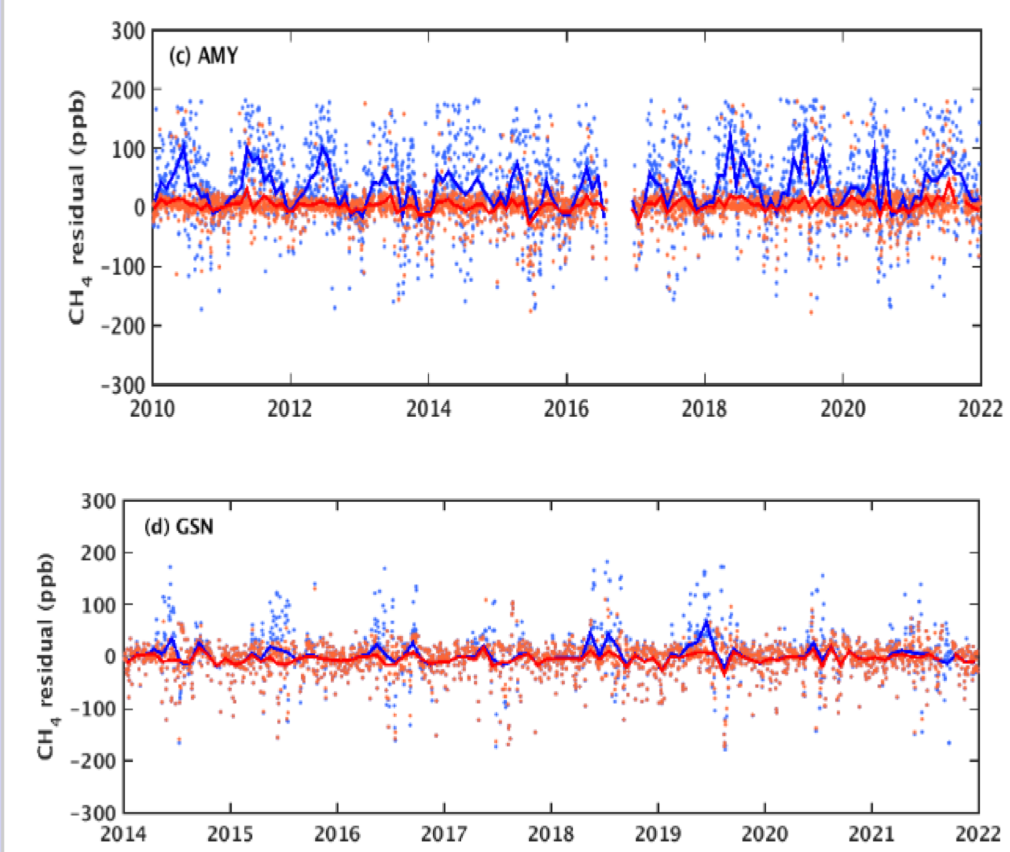

Fig. 5. Time series of CH_4 residuals (model–observations) at AMY (c) and GSN (d), comparing simulations based on prior (blue) and posterior (red) emissions

✓Residual analysis shows reduced bias and RMSE at AMY and GSN after inversion.

✓Bias improved: AMY from +29.9 ppb (prior) to +0.34 ppb (posterior); GSN from +2.01 ppb to −3.39 ppb.

✓Seasonal bias (spring peak) in prior largely corrected in posterior.

➢Sensitivity analysis: Observation, prior emission, its uncertainty

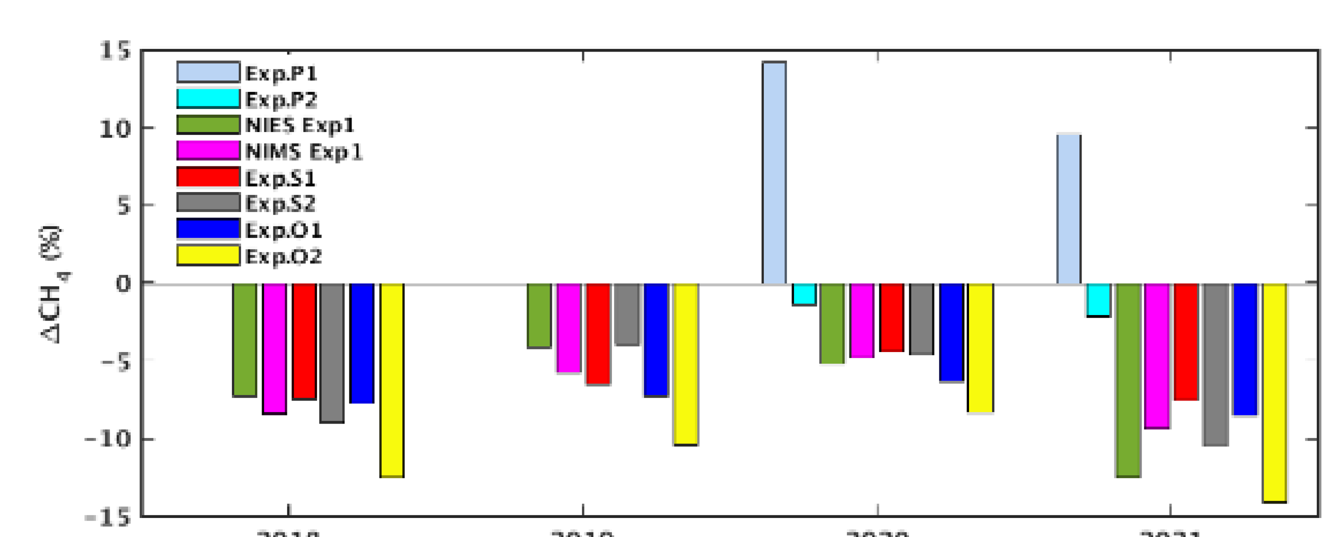

Fig. 6

✓Varying prior uncertainty (halved/doubled) changed posterior fluxes by <0.7% → indicates low sensitivity to prior uncertainty.

✓Changing prior magnitude (±50%) had strong impact: posterior adjusted up to -2.1%/14.2%, respectively

✓Observation site impact: AMY alone (Exp.O1) ≈ base inversion; adding ULD (Exp.O2) → up to −11.1% posterior reduction.

Conclusion

○The Bayesian inversion reveals consistent overestimation of CH_4 emissions in bottom-up inventories.

○Expanding observational networks and incorporating seasonal dynamics are critical for improving national CH_4 inventories

Acknowledgements

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