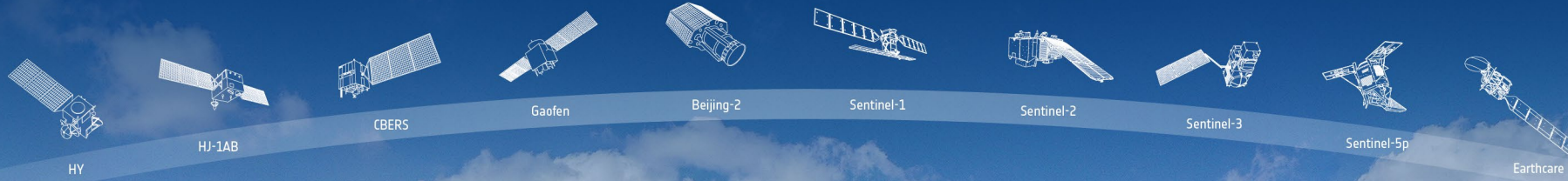




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2025 DRAGON 6 SYMPOSIUM

16 JULY 2025

[PROJECT ID. 95396]

[MONITORING GREENHOUSE GASES FROM SPACE]





**16/JULY/2025 & 11:00-12:40 D6-2: ATMOSPHERE - ECOSYSTEMS
ID. 59396**

PROJECT TITLE: MONITORING GHGS FROM SPACE

PRINCIPAL INVESTIGATORS: YI LIU, LIANG FENG

**CO-AUTHORS: PAUL PALMER, HARTMUT BOESCH, ROBERT PARKER, JOHANNA TAMMINEN, HANNAKAISA
LINDQVIST, ANTTI MIKKONEN, JIA CHEN, DONGXY YANG, ZHAONAN CAI, JING WANG, SIHONG ZHU, LU
YAO, DANLING TANG, WEICHEN ZHOU**

PRESENTED BY: YI LIU



WP1: Evaluation of CO₂ and CH₄ satellite retrievals using a combination of ground-based measurements of CO₂ and CH₄ and data from current satellite observations (TanSat/-2, GOSAT/-2,OCO-2/-3, TROPOMI and CO₂M, MicroCarb).

WP2: Evaluation of CO₂ and CH₄ satellite retrievals with retrieval intercomparisons and model Comparisons.

WP3: Flux inverse methods to assess estimates of CO₂ and CH₄ surface fluxes and emissions.

WP4: City scale remote sensing of GHGs and carbon flux inversion, we focus on the estimation of anthropogenic CO₂ emission on urban-scale.

WP5: Quantify Methane Emissions from Surface Ocean.

WP6: Publication, Exchanges, Training Exchange of staff and training of young researchers.



Plan on the level and training of young scientists on the project achievements, including academic exchanges

2025 7 - 2025 12 Dongxu Yang, Jing Wang, University of Edinburgh, UK

2025 9 – 2025 10 Dongxu Yang, academic visiting in University of Bremen, German

2026 09 - 2026 10 Young Scientist from FMI visit IAP, academic exchanges

2026 01 – 2027 12 Joint PhD student in IAP and University of Edinburgh, UK

2024 07 - 2026 06 Training of young scientists on the project objectives of WP1 –WP 4

Dragon 6 EO Data Delivery



ESA /Copernicus Missions	No. Scenes	ESA Third Party Missions	No. Scenes	Chinese EO data	No. Scenes
1. TROPOMI L2 products		1. TanSat L1 and L2 products		1. TanSat-2 L1 and L2 products	
2. CO2M L1 and L2 products		2. GOSAT-1/2/GW L2 products		2. GF-5, DQ-2 , FY-3D L2 products	
3. MicroCarb L1 and L2 products		3. OCO-2/3 L2 products		3. Xianghe TCCON station	
4.		4.		4. COCCON moving validation system	
5.		5.		5.	
6.		6.		6.	
Total:		Total:		Total:	
Issues:		Issues:		Issues:	

Overview of research plan

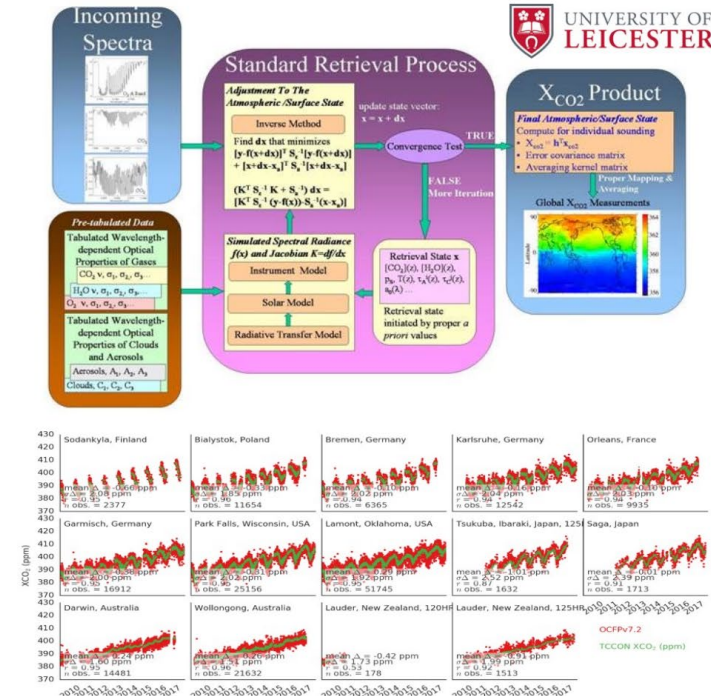
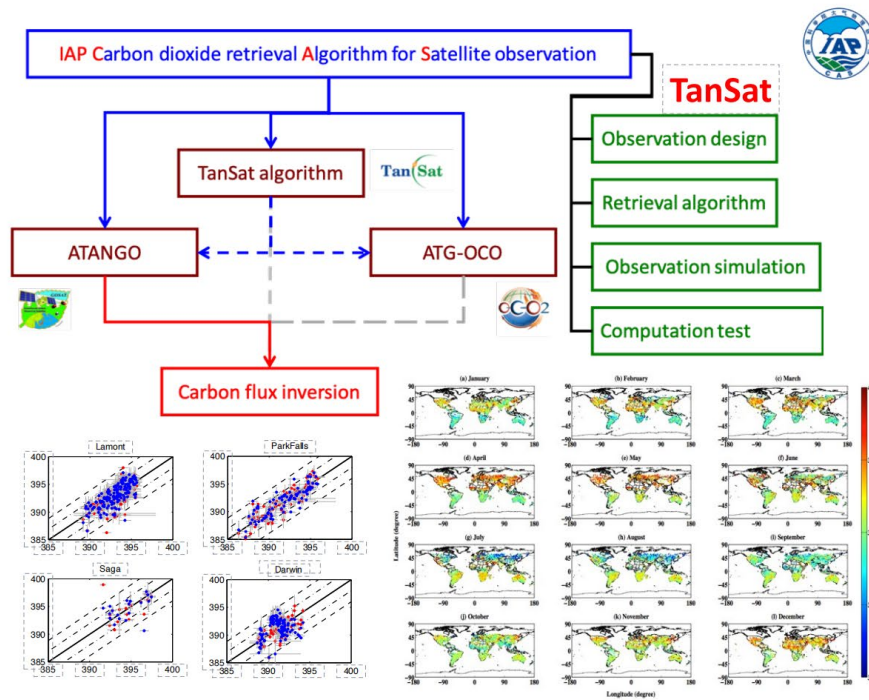


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2 different retrieval algorithms for TanSat: IAPCAS and UoL-FP



ESA CCI+



UNIVERSITY OF
LEICESTER



CO₂ Retrieval Algorithms



Overview of research plan

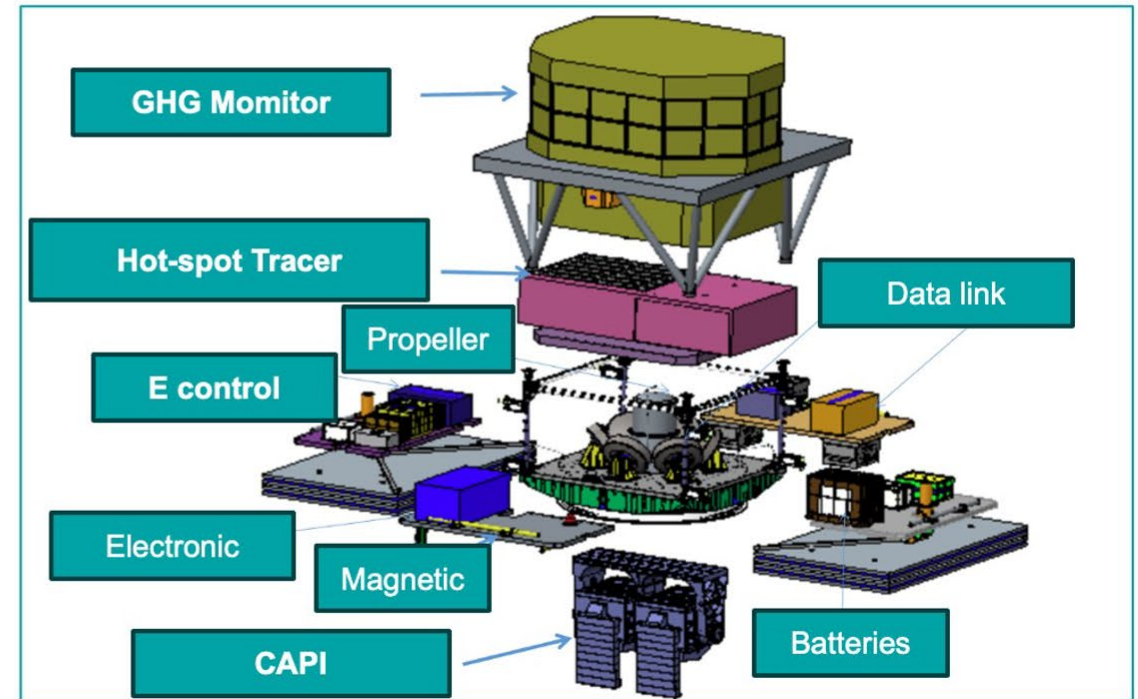
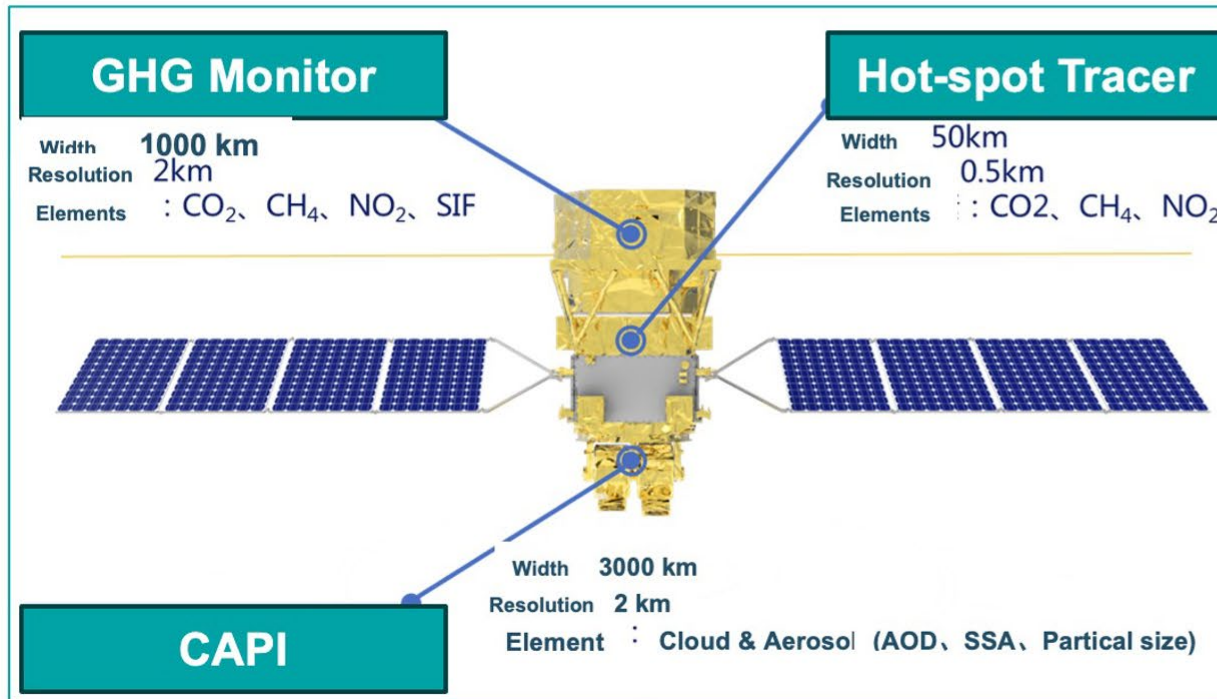


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TanSat-2 carries three payload instruments



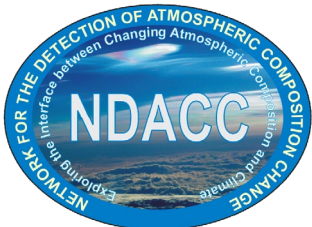


Introduction to the International Observation Networks

Detection of Atmospheric Composition Change – the Infrared Working Group

NDACC IRWG

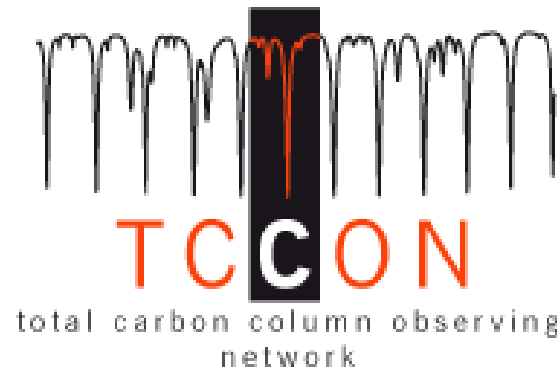
- mainly Bruker IFS 120HR/125HR
- thermal infrared 800 - 4800 cm^{-1}
- 0.0036 – 0.005 cm^{-1}
- profile/column concentration
- single measurement time ~10 mins



Total Carbon Column Observing Network

TCCON

- Bruker IFS 125HR
- near infrared 4800 - 16000 cm^{-1}
- 0.02 cm^{-1}
- column concentration
- single measurement time - 3 mins



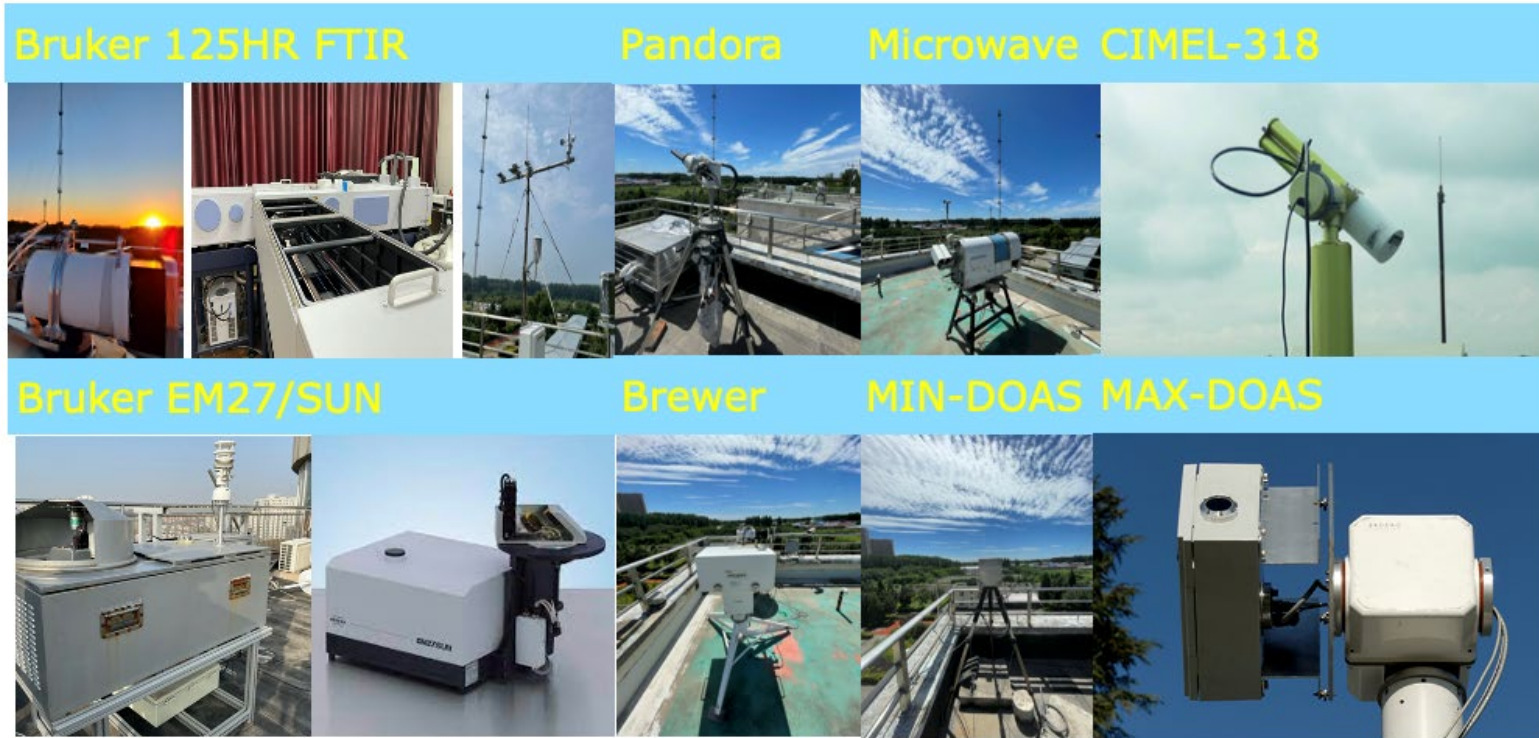
COllaborative Carbon Column Observing Network COCCON

- Bruker EM27/SUN
- near infrared 4800 - 12000 cm^{-1}
- 0.5 cm^{-1}
- column concentration
- single measurement time - 1 min





Remote sensing instruments at Xianghe (IAP)



- Band: cover UV, VIS, IR
- pollutant gases, greenhouse gases, aerosols,
- near-surface, troposphere, stratosphere
- Strong international collaboration, e.g., TCCON, GAW, COCCON, AERONET...



Overview of research plan



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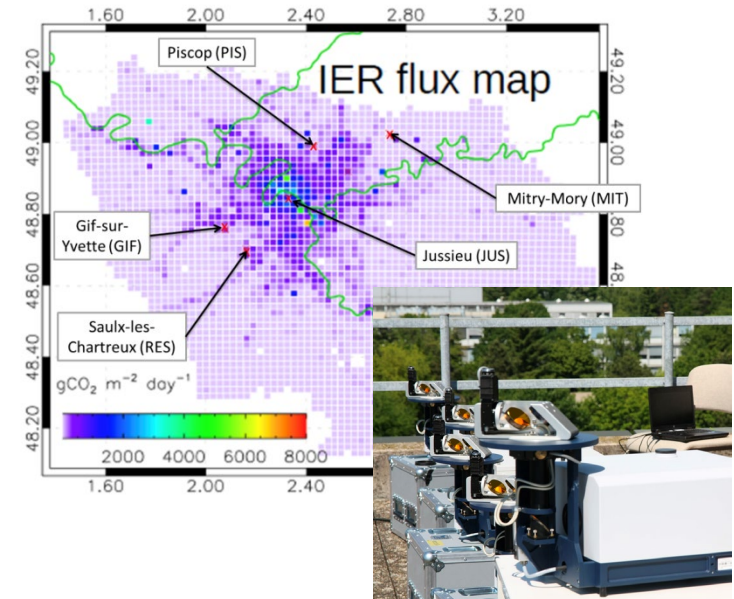
COCCON



Airborne



Shipborne



Urban networking
observation experiment



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TanSat-2 assessment

Overview of research plan



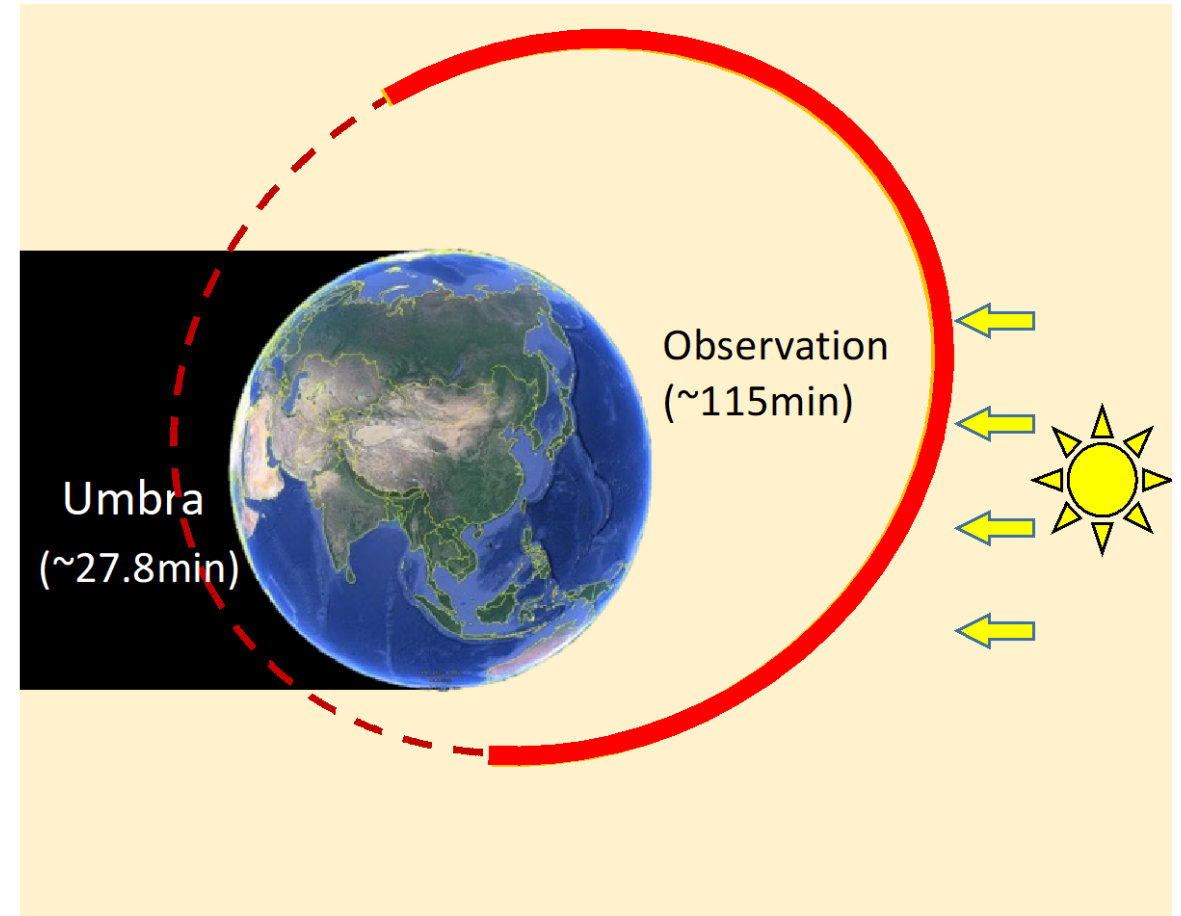
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Orbit type: Critically Inclined, Sun Synchronous, ellipse MEO

Parameters	Value
Perigee altitude	~522km
Apogee altitude	~7840km
Inclination	116.565°
Latitude at Apogee	35°N
Argument of Perigee	210°
Revisit Period	1 day



Why ellipse orbit ?

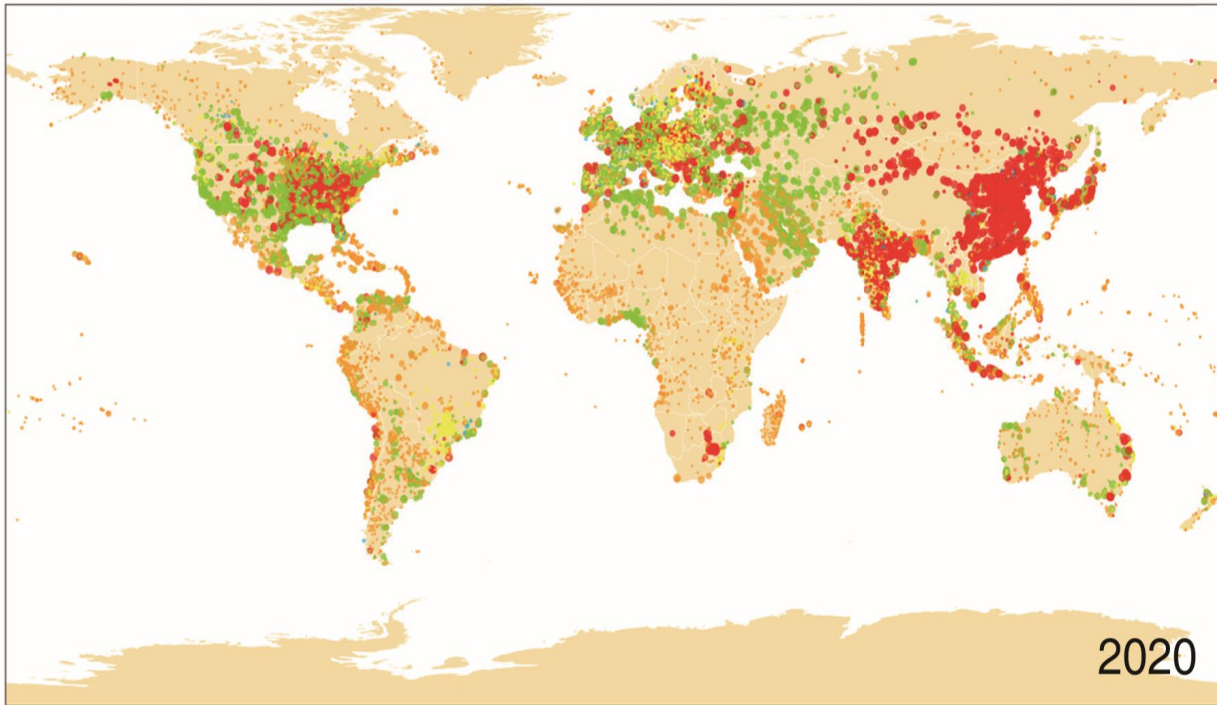


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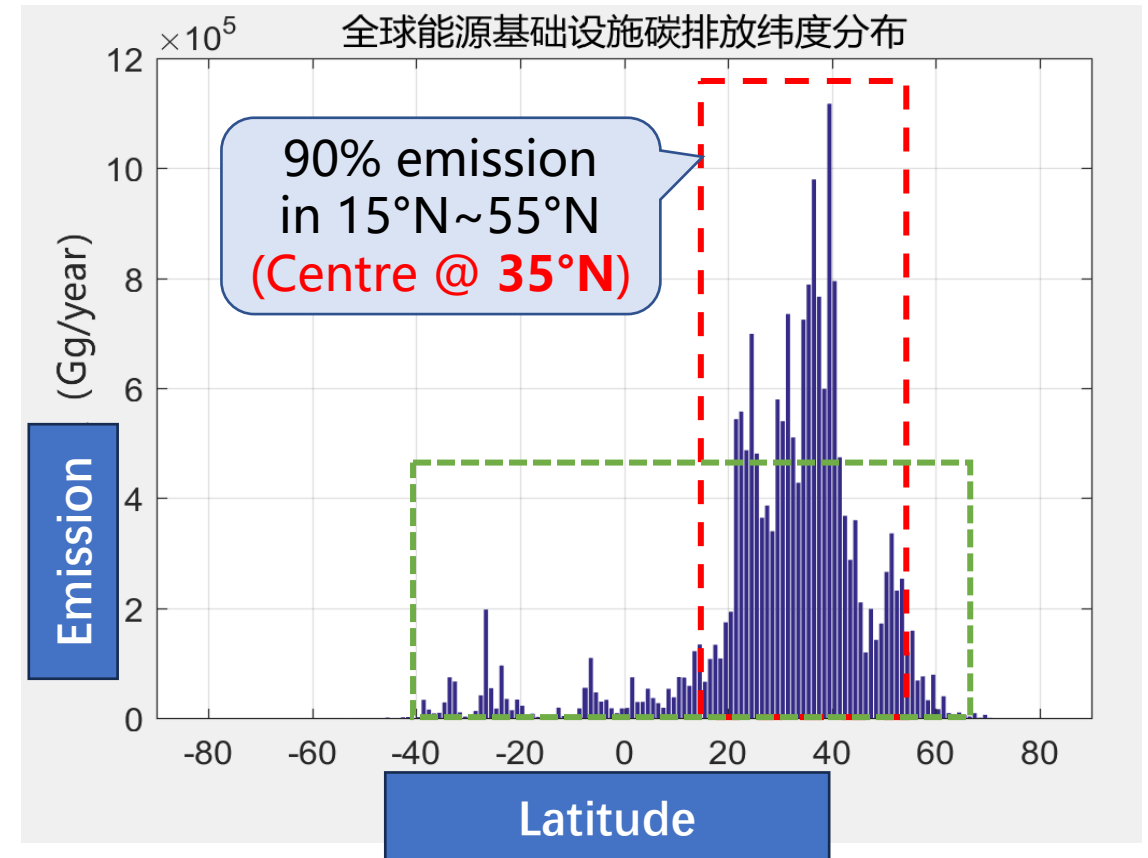


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Global carbon emissions are highly concentrated in the Northern Hemisphere



The major economies are mainly located in the Northern Hemisphere



OSSE for CO₂ and CH₄ measurement

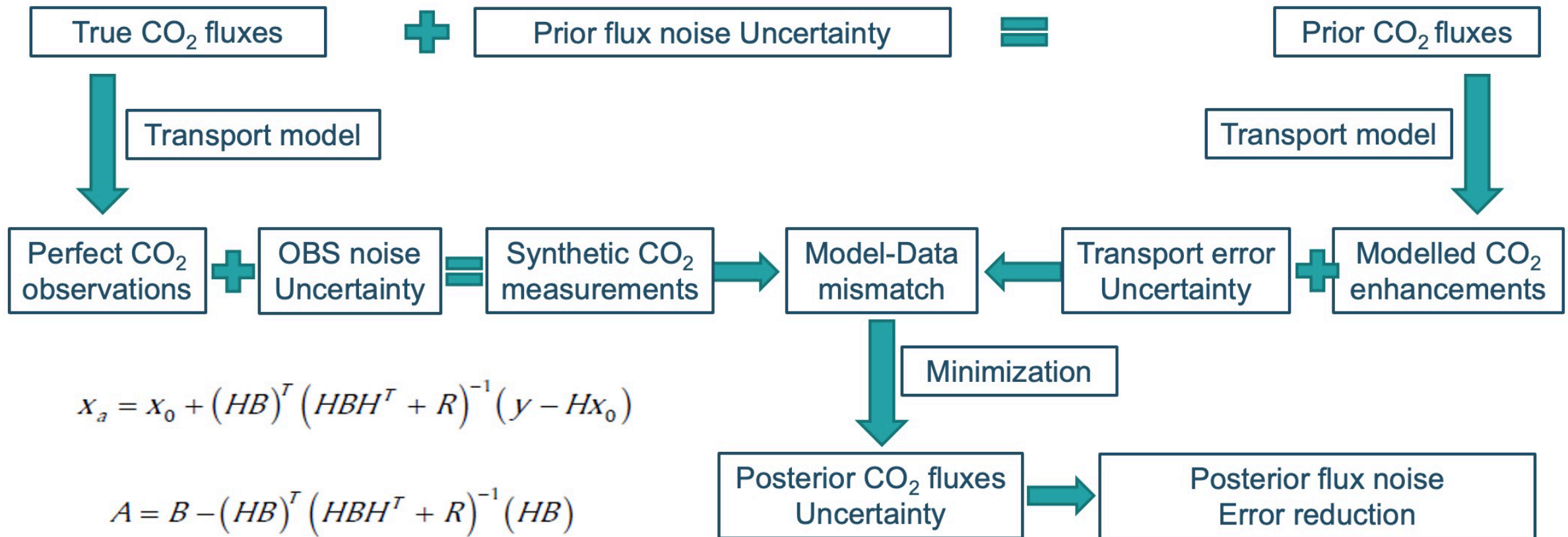


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To **minimize** the mismatch between observed and modeled [CO₂] by **optimizing** the prior fluxes





- Correction in systematic flux errors is sizable, subject to unbiased satellite sampling and favorable meteorological conditions (less cloud cover and low wind speed).

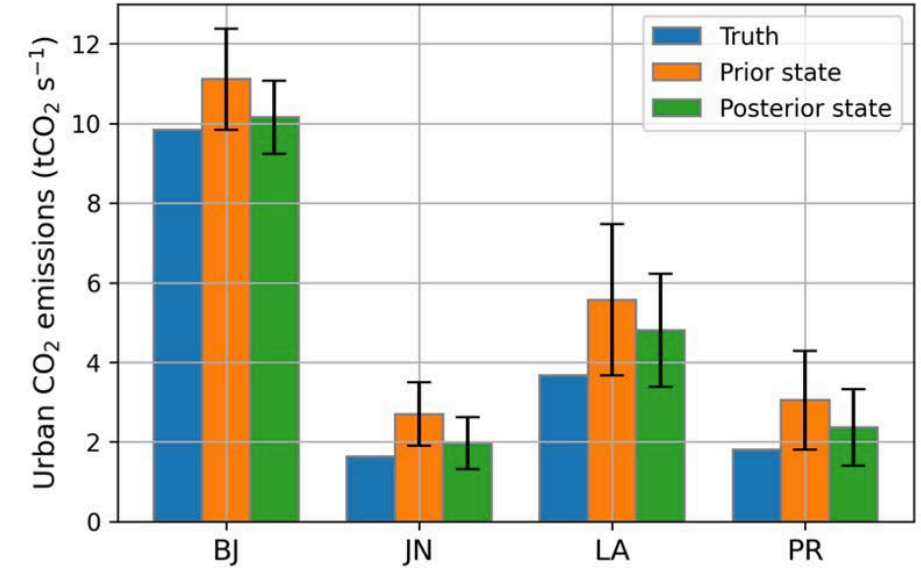
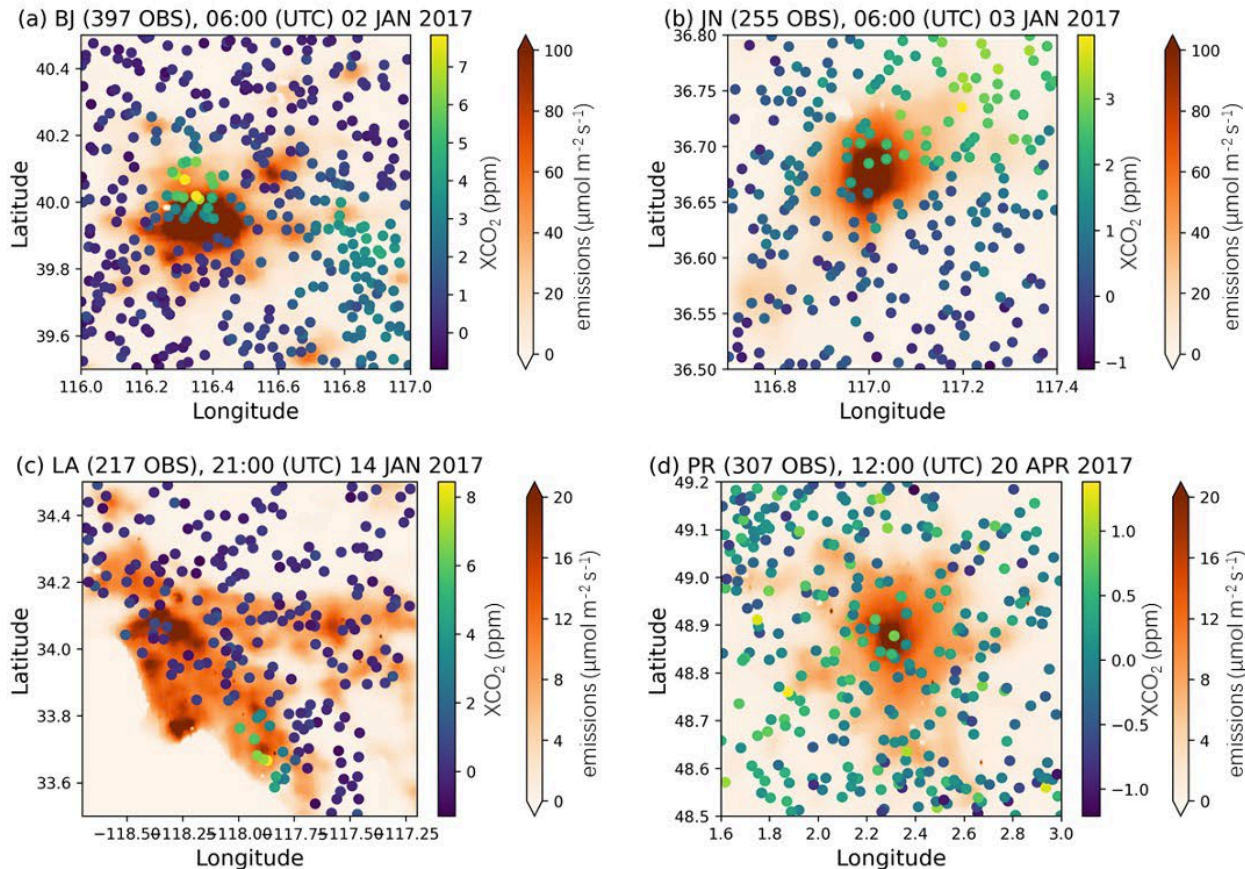


Table 1. Reduction of flux bias and random error (RE) and overall correction (OC) of integrated urban CO₂ emissions in Beijing (BJ), Jinan (JN), Los Angeles (LA), and Paris (PR). Units are %.

City	Bias	RE	OC
BJ	75	28	46
JN	68	19	45
LA	40	25	32
PR	56	23	37

Point source emissions

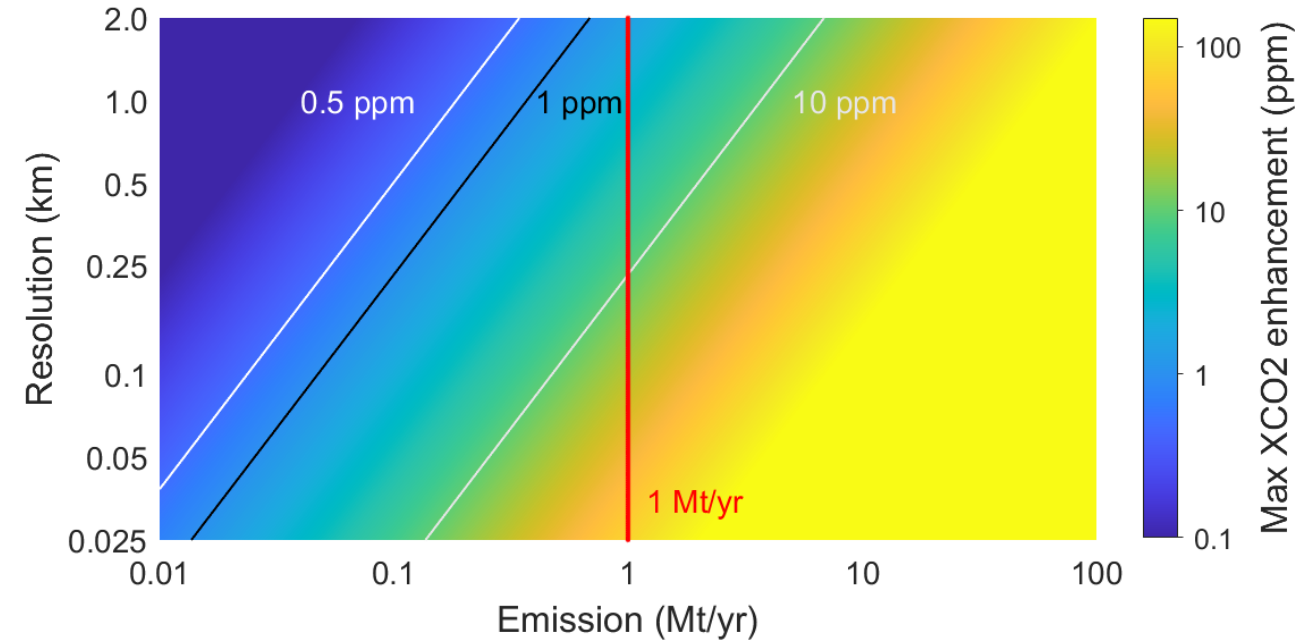


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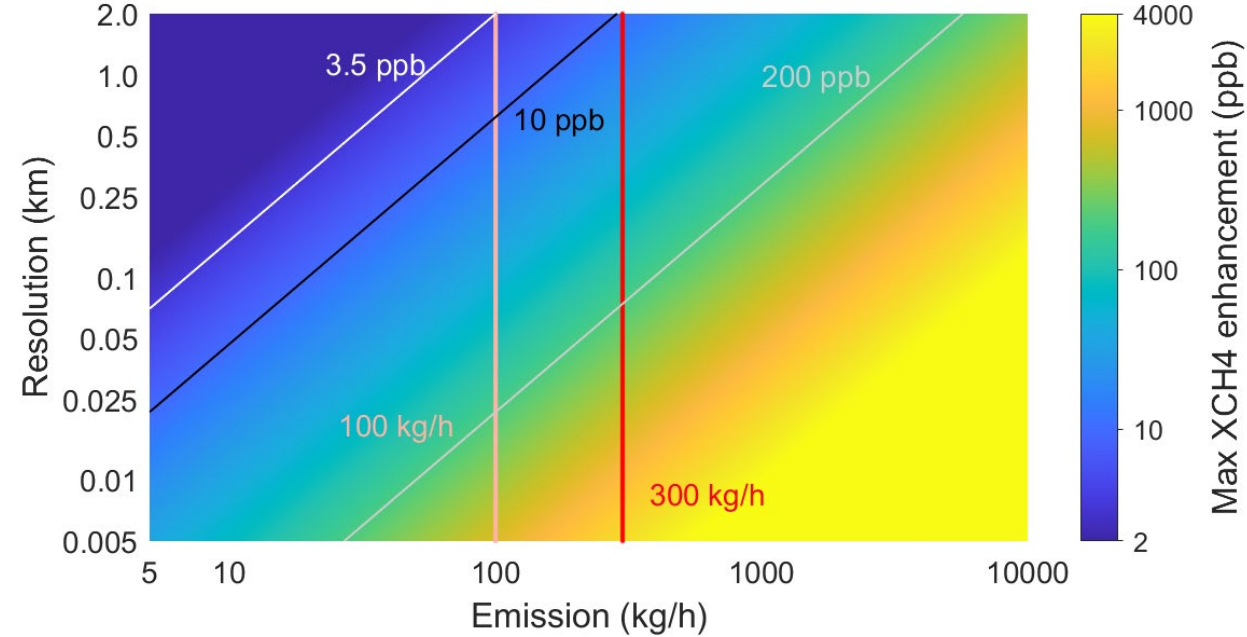


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CO₂, wind speed = 3m/s



CH₄, wind speed = 3m/s



- With the simulated plumes, the maximum concentration enhancement of the emission plume from pixel scales can be used to infer the satellite detection ability.
- Satellite measurements with a spatial resolution of 2×2 km² and a measurement precision of 1.4 ppm can detect 88% of the total CO₂ emissions from power plants.
- satellite measurements with at a spatial resolution of 0.5×0.5 km² and a measurement precision of 10 ppb can detect 95% of the total CH₄ emissions from power plants.

Point Source quantification capability

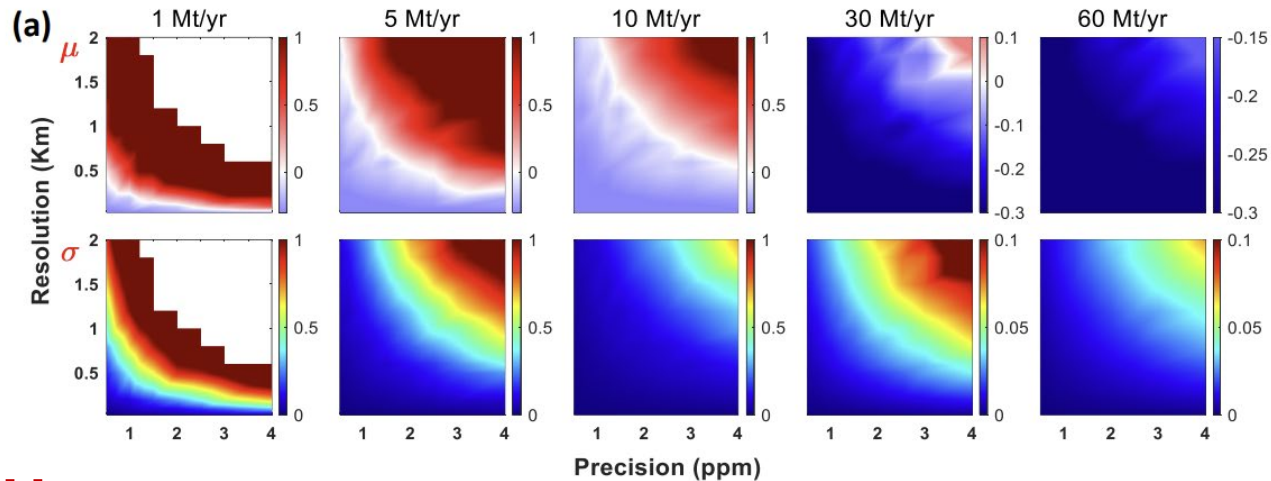


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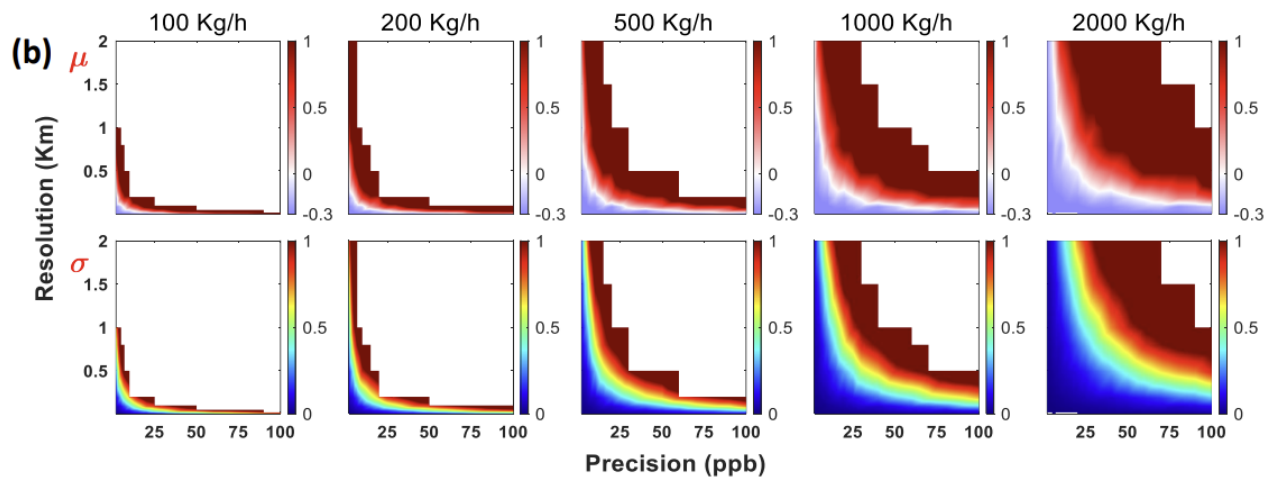
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CO₂



- TanSat-2 can theoretically quantify CO₂ point source emissions with an intensity above **10 Mt/yr** at a wind speed of 3 m/s.

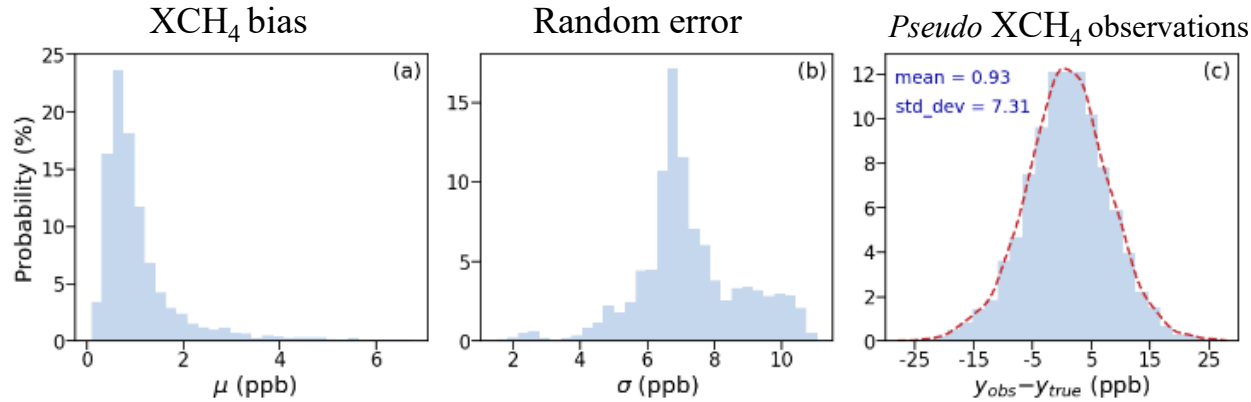
CH₄



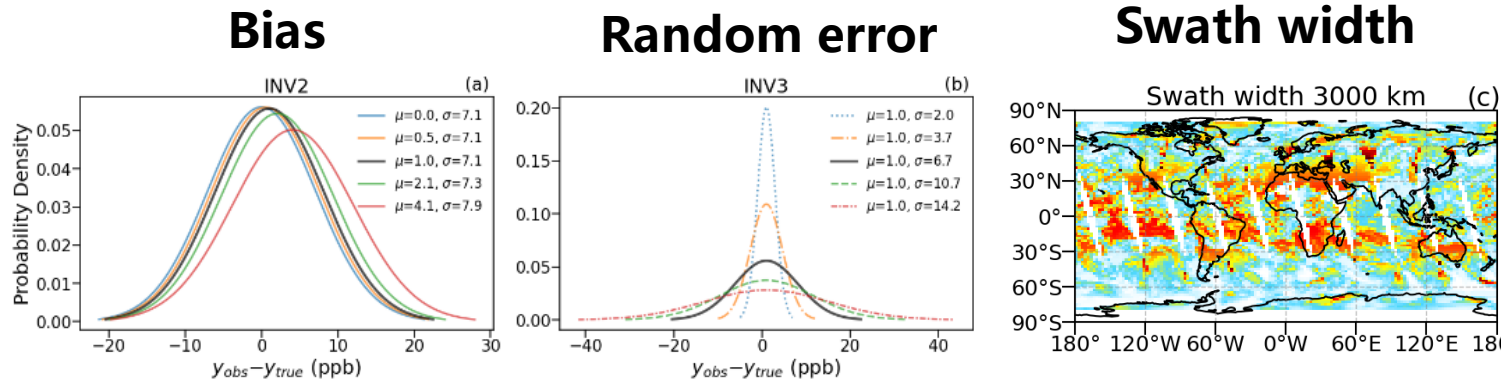
- Due to the relatively low emission intensity, accurate quantification of CH₄ requires higher spatial resolution.

(Yao et al., 2024)

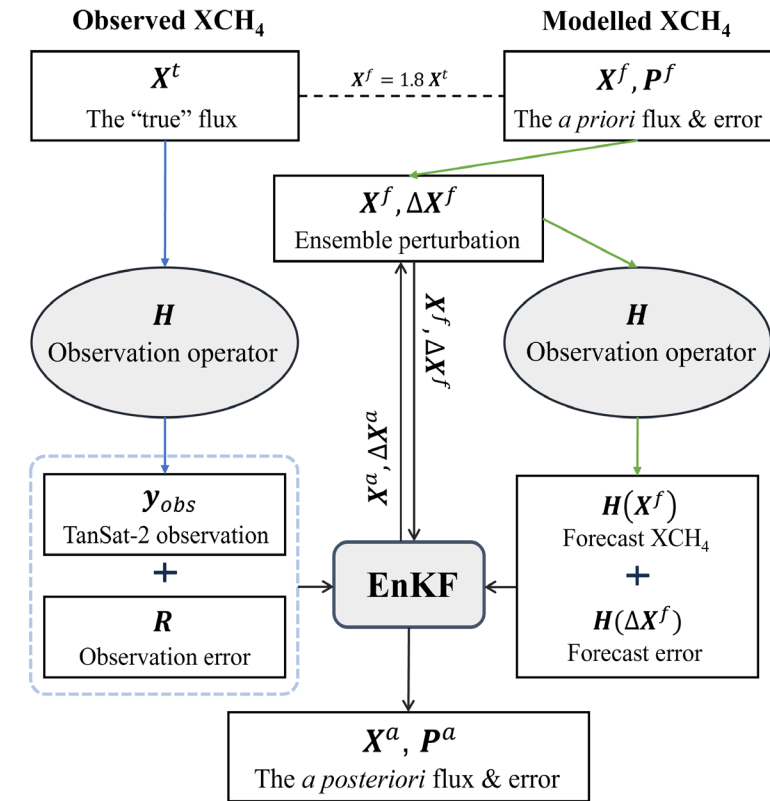
Observing System Simulation Experiments (OSSEs)



Experimental Design:



OSSEs diagram:

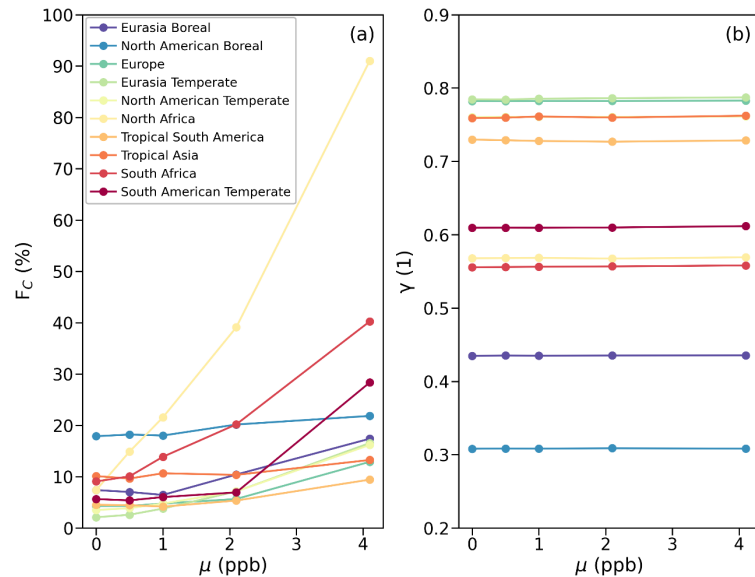


TanSat-2 is theoretically capable of achieving a global CH₄ emission estimation accuracy of **$3.1 \pm 2.2\%$** .

(Zhu et al., 2025a)

Global and regional CH₄ emission qualification

XCH₄ Bias



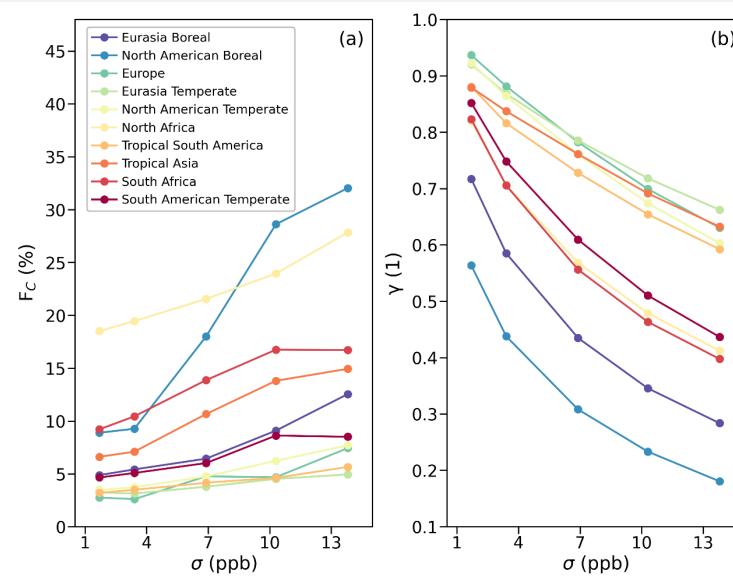
Africa is highly sensitive to XCH₄ biases, with accuracy decreasing by **20% ppb** in **North Africa** and **8% ppb** in **South Africa**.



Global mean bias: could be corrected

Spatial Variable bias*: highly impact inversion accuracy

XCH₄ random error

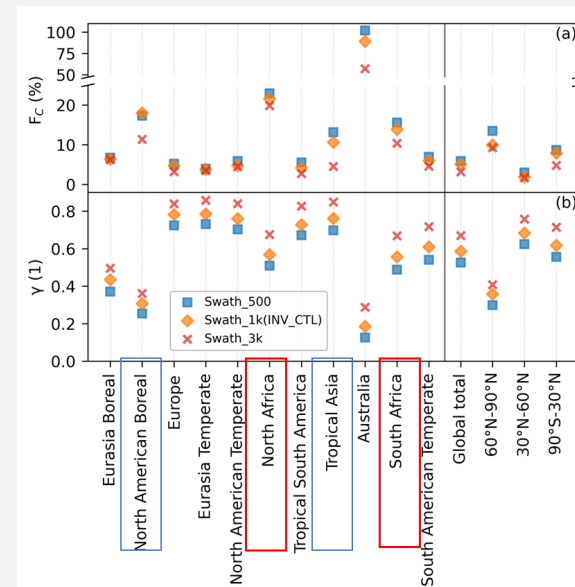


North America Boreal and Tropical Asia are sensitive to **random errors** in XCH₄.

Suggestions for satellite Design:

Given a fixed budget, priority should be placed on improving **XCH₄ retrieval accuracy (Fourier spectrometer or cloud-aerosol imager)**, rather than **swath width**.

Satellite Swath width



Expanding **swath width**:
limited effect on **bias-sensitive regions**



China's CH₄ emission quantification

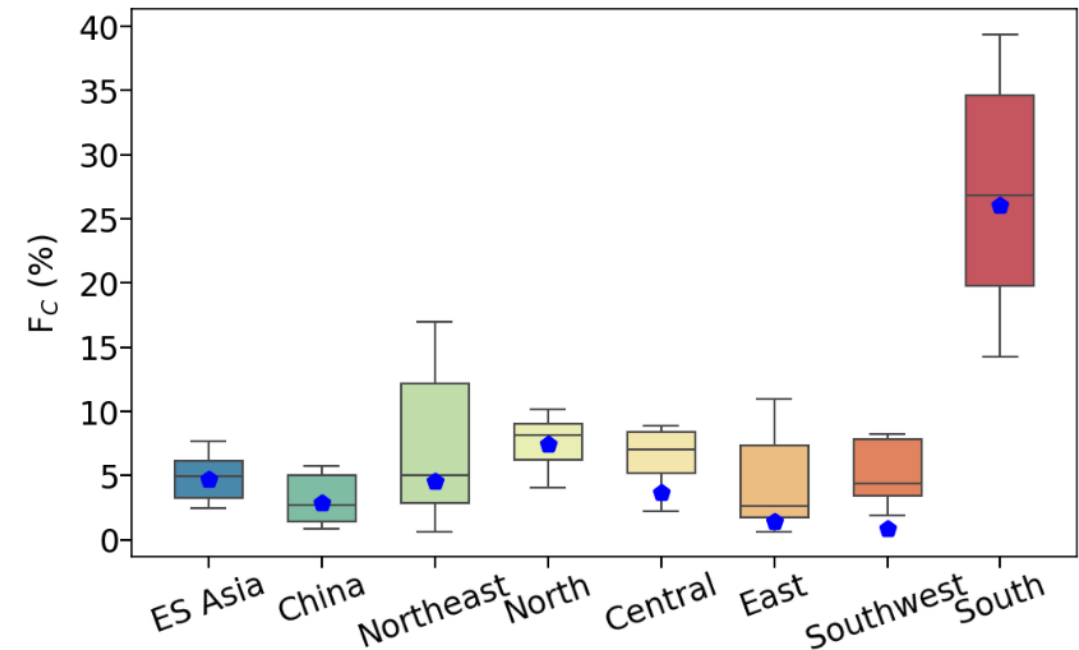
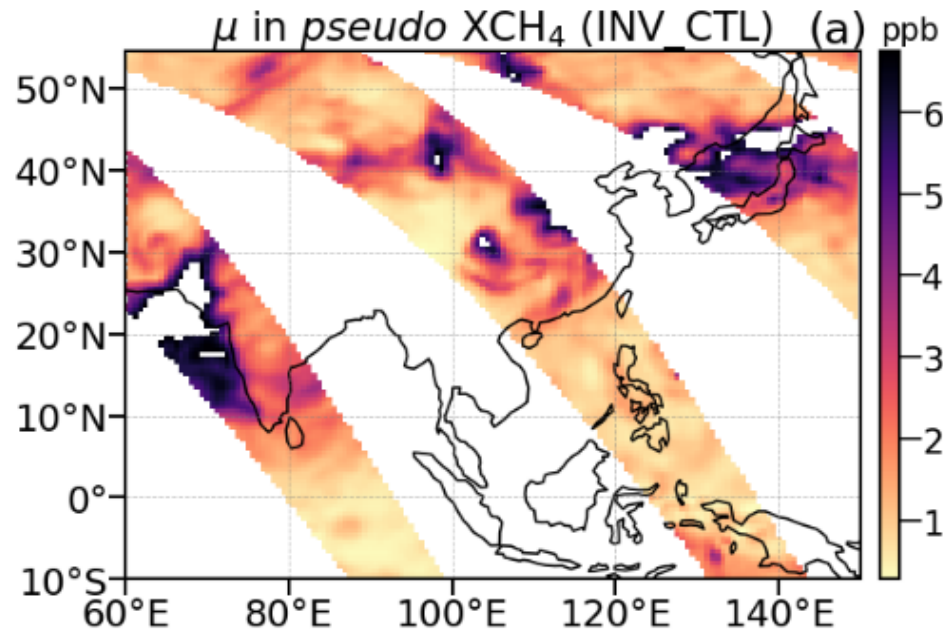


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High temporal and spatial resolution: 1- week; 0.5° × 0.625°



- TanSat-2 could theoretically achieve an accuracy of **2.9% ± 4.2%** in annual CH₄ emission estimates over China
- In **South China**, **persistent cloud cover** substantially limits observational coverage, resulting in larger discrepancies (26.1%), highlighting the need of **complementary ground-based CH₄ monitoring**.

(Zhu et al., 2025b)



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CH₄ over ocean

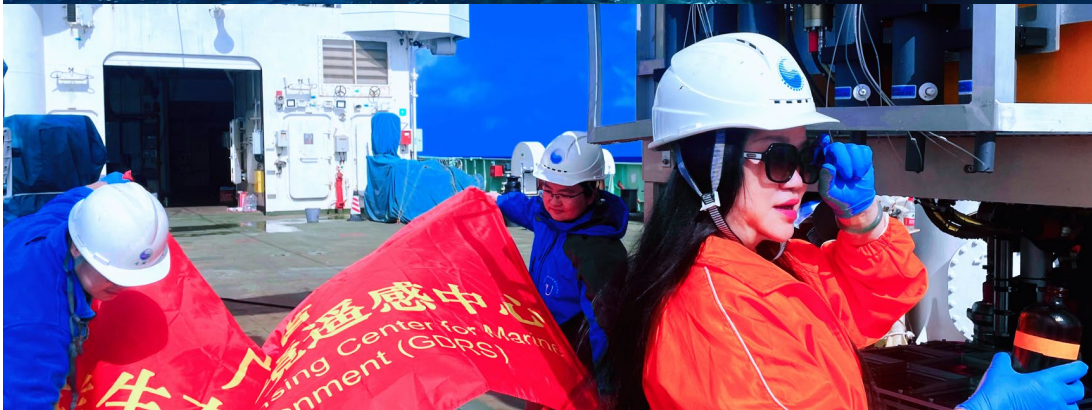
Overview of research plan



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➤ Research Background:

- Importance :
 1. strong greenhouse effect
 2. large uncertainty in its quantification in marine areas.
- Challenges :
 1. Scarcity of methane measurements in marine regions.
 2. Shortwave infrared (SWIR) reflectance in marine areas is too low to obtain reliable data.

➤ Research Objectives:

- Utilize remote sensing technology to monitor methane concentrations in the **sea surface atmosphere** and **water bodies**.
- Develop novel data processing and analysis methods to enhance monitoring accuracy.

Overview of research plan



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PI : Professor DnLing Tang

2024 methane survey cruise



SCS U-Team, Guangdong Marine lab (GML)

Filling Data Gaps: AI-Assisted Atmospheric CH₄ Reconstruction

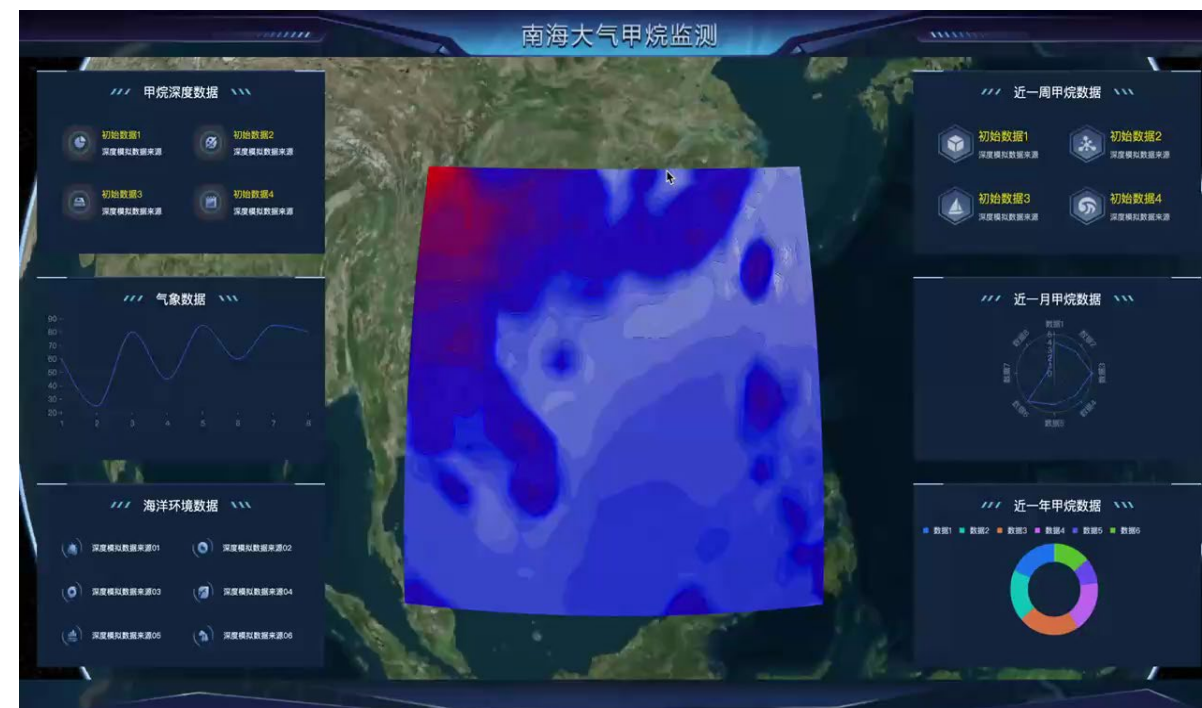
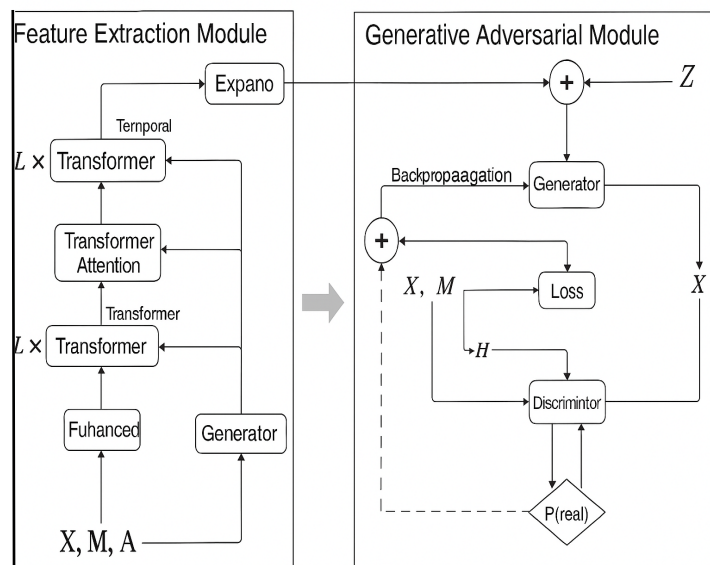


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- Issue: sparse satellite CH₄ over oceans due to low SWIR and clouds
- Method: graph neural networks + GANs to interpolate missing data
- System prototype: automated atmospheric CH₄ map reconstruction system



The prototype system has been established and is currently being integrated with data.

Architecture of the Methane Gap-Filling Model Using Spatiotemporal Attention and Generative Adversarial Networks



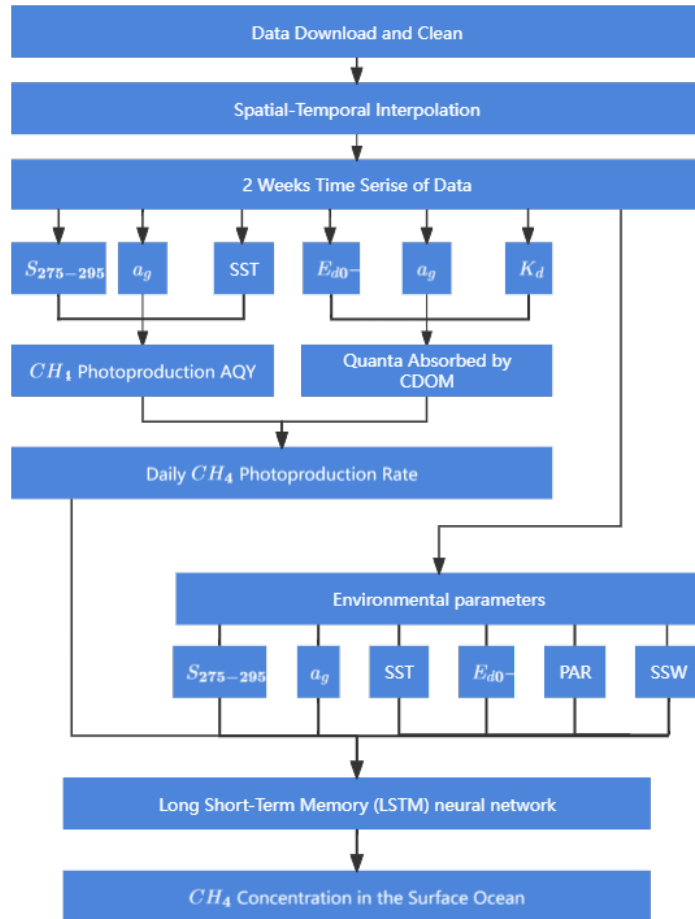
Estimating Sea Surface Methane from Remote Sensing with Machine Learning



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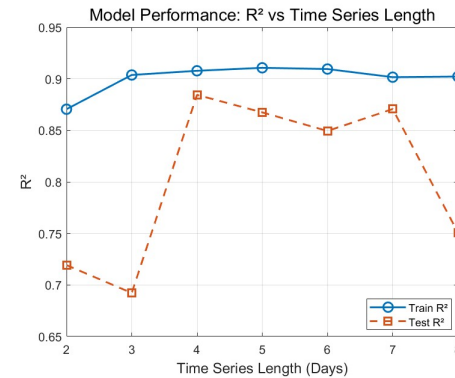


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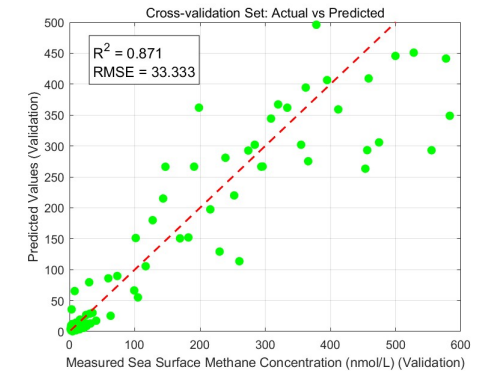
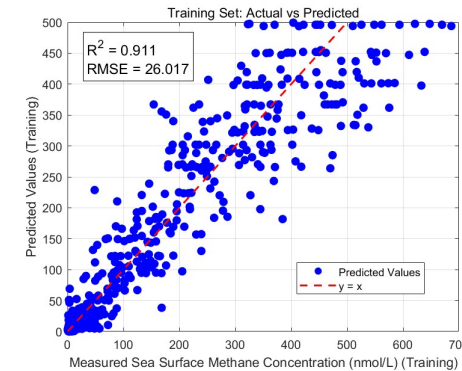


Flow chart of the process of surface water CH_4 concentraion data production

- Inputs: Rrs, SST, wind speed, and modeled solar radiation reached sea surface
- Model: LSTM-based neural network incorporating time-lag effects
- Output: daily surface water CH_4 concentration
- Current performance: $R^2 = 0.87$ on validation dataset



Hydro-parameter tuning of input time serise length



Model performance in both training and cross validation data set.



1. Yang, D.; Hakkarainen, J.; Liu, Y.; Ialongo, I.; Cai, Z.; Tamminen, J. Detection of Anthropogenic CO₂ Emission Signatures with TanSat CO₂ and with Copernicus Sentinel-5 Precursor (S5P) NO₂ Measurements: First Results. *Adv. Atmos. Sci.* **2023**, *40*, 1–5. <https://doi.org/10.1007/s00376-022-2237-5>.
2. Wu, K.; Yang, D.; Liu, Y.; Cai, Z.; Zhou, M.; Feng, L.; Palmer, P.I. Evaluating the Ability of the Pre-Launch TanSat-2 Satellite to Quantify Urban CO₂ Emissions. *Remote Sens.* **2023**, *15*, 4904. <https://doi.org/10.3390/rs15204904>.
3. Yao, L.; Yang, D.; Jiang, Z.; Liu, Y.; Chen, L.; Tian, L.; Hakkarainen, J.; Cai, Z.; Wang, J.; Ren, X. Towards Supporting Satellite Design Through the Top-Down Approach: A General Model for Assessing the Ability of Future Satellite Missions to Quantify Point Source Emissions. *Remote Sens.* **2024**, *16*, 4503. <https://doi.org/10.3390/rs16234503>.
4. Zhu, S.; Yang, D.; Feng, L.; Tian, L.; Liu, Y.; Cao, J.; Wu, K.; Cai, Z.; Palmer, P.I. Towards the Optimization of TanSat-2: Assessment of a Large-Swath Methane Measurement. *Remote Sens.* **2025**, *17*, 543. <https://doi.org/10.3390/rs17030543>.
5. Zhu, S.; Yang, D.; Feng, L.; Tian, L.; Liu, Y.; Cao, J.; Zhou, M.; Cai, Z.; Wu, K.; Palmer, P.I. Theoretical Potential of TanSat-2 to Quantify China's CH₄ Emissions. *Remote Sens.* **2025**, *17*, 2321. <https://doi.org/10.3390/rs17132321>.

Thanks you!