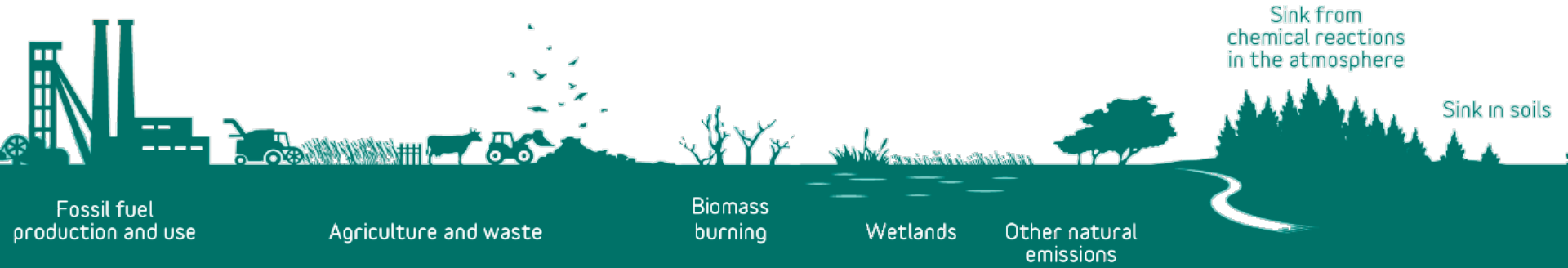
西湖大學
WESTLAKE UNIVERSITY

Inferring long-term trends in methane emissions from satellite and ground-based observations

从卫星和地面观测推断甲烷排放的长期趋势

Yuzhong Zhang 张羽中



Acknowledgement

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Daniel Jacob, Jianxiong Sheng, Xiao Lu, Tia Scarpelli,
Daniel Varon, Lu Shen, Zhen Qu, Hannah Nesser

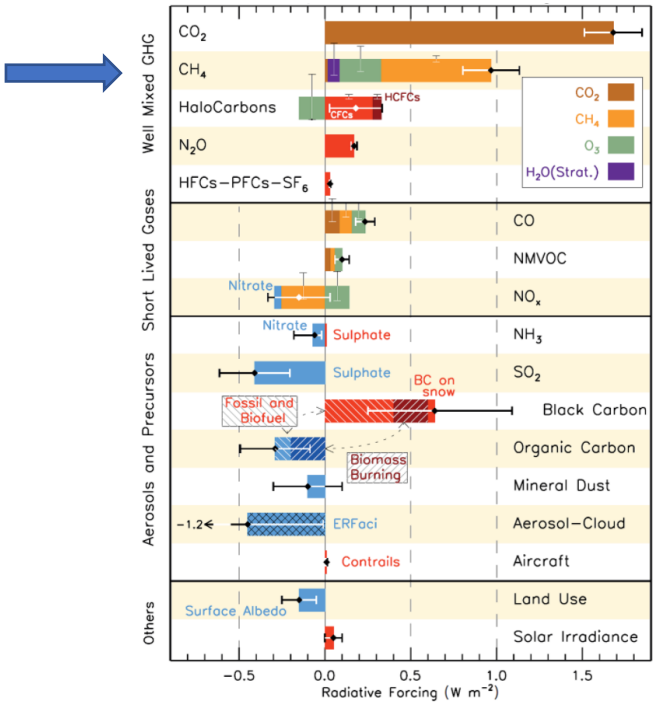
EDF
Ritesh Gautam, Mark Omara, Daniel Zavala-Araiza, David Lyon

JPL John Worden, Anthony Bloom, Shuang Ma

SRON Ilse Aben, Bram Maasakkers, Sudhanshu Pandey

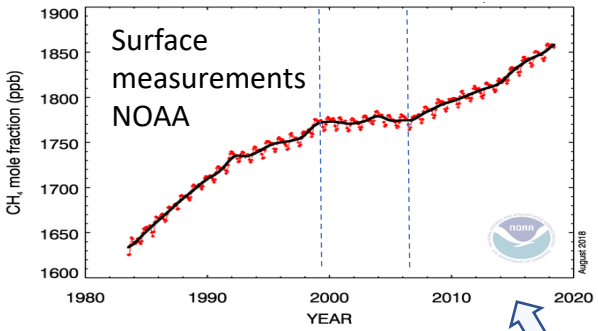
Methane: a greenhouse gas 温室气体甲烷

Radiative forcing

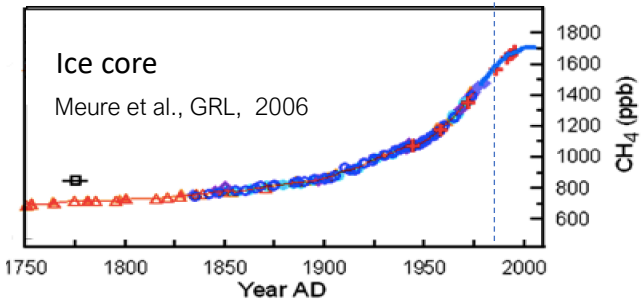


IPCC AR5

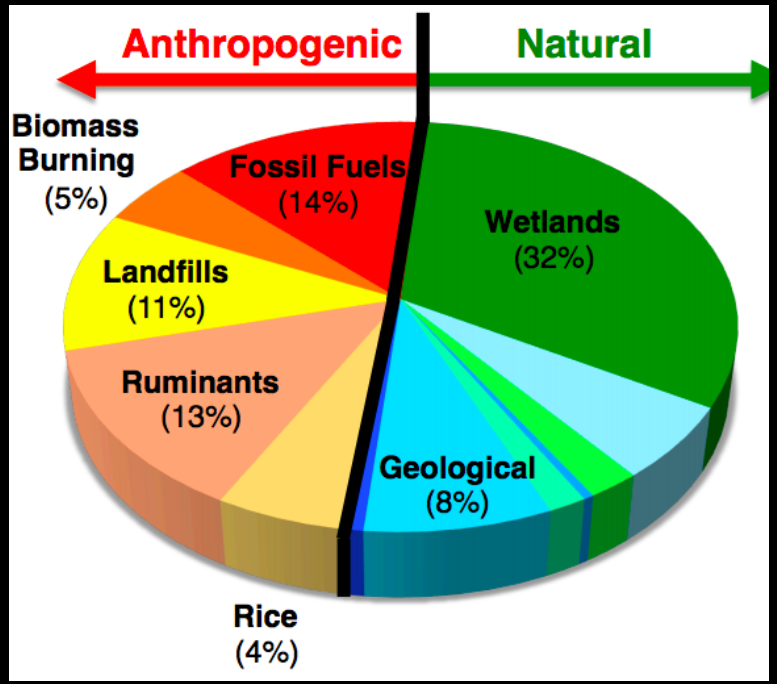
Methane concentration in last 35 years



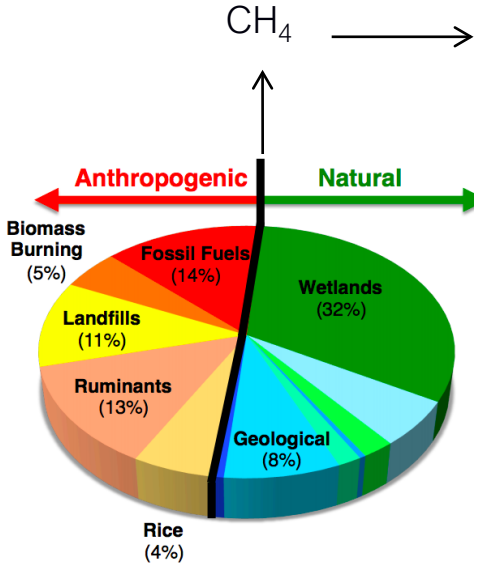
Methane concentration in last 300 years



Methane sources 甲烷排放源



Methane sinks 甲烷的大气汇



Sources

550 ± 60 Tg a^{-1}

Sink

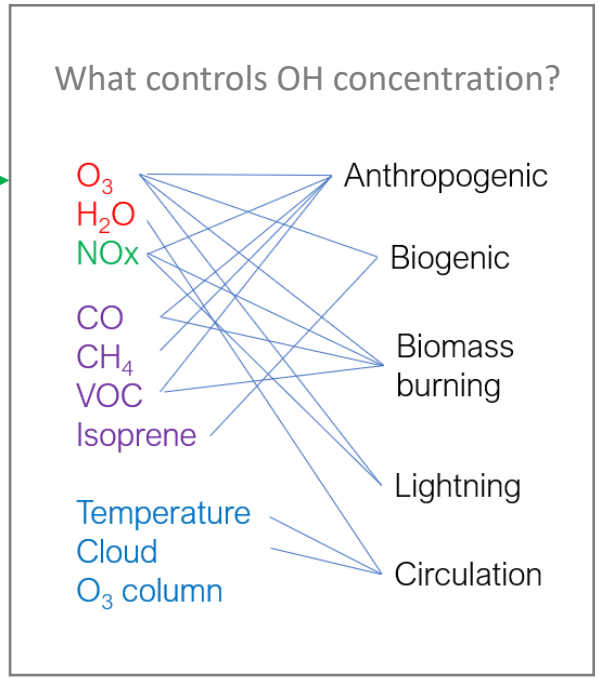
Lifetime of 10 yrs

Tropospheric OH 89%

Soil Absorption

Stratospheric Loss

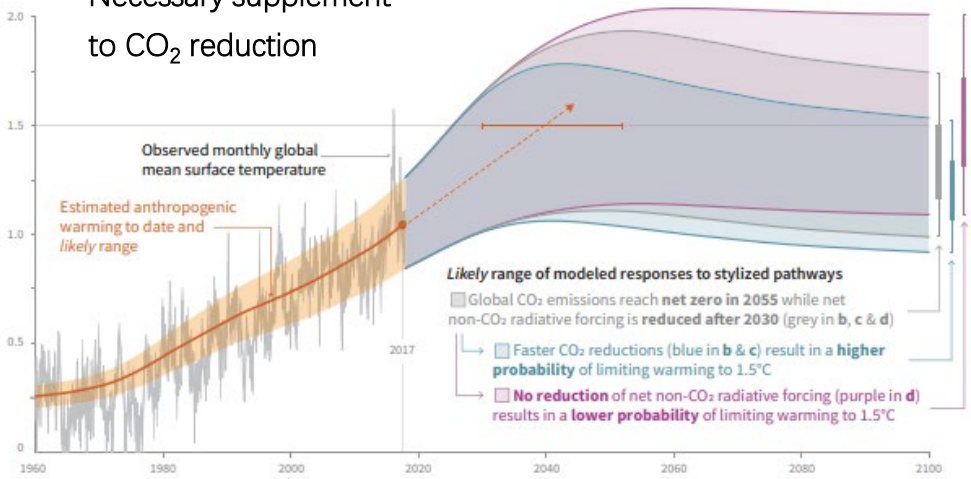
Tropospheric Cl



Reducing methane emissions 甲烷减排

必要性

Necessary supplement to CO_2 reduction



IPCC, 2018

可行性

Methane emission reduction is feasible in at least some sectors such as oil & gas:

- Economical value
- Technology

Global Methane Initiative
政府

OIL AND GAS CLIMATE INITIATIVE
油气企业

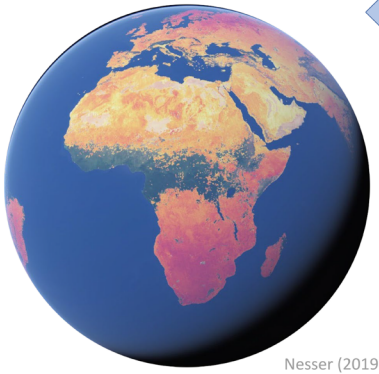
METHANE GUIDING PRINCIPLES
企业+民间+学术界

Science questions 科学问题

from global scale to point sources

Global/national Scale

- Global budget
- Climate feedback
- Verification of national inventory

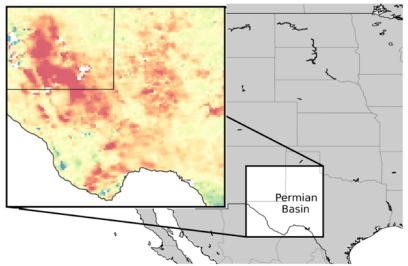


Nesser (2019)

500 km resolution

Regional Scale

- Resolve regional hotspots spatially and temporally
- Gain knowledge about underlying processes
- Guide facility-scale monitoring

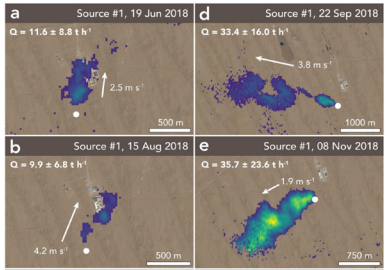


Zhang et al. (2020)

10 km resolution

Facility Scale

- Pinpoint anomalous emitters
- Inform stakeholders for actions: checking, fixing, accounting···



Varon et al. (2019)

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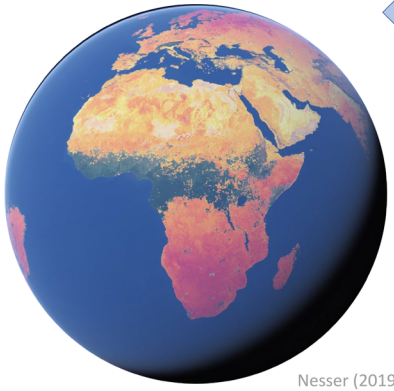

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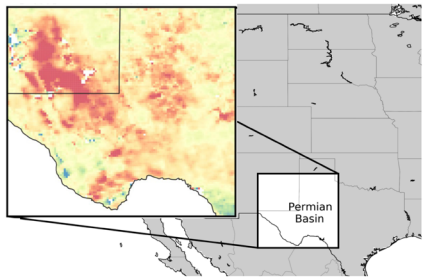

Zhang et al. (2020)

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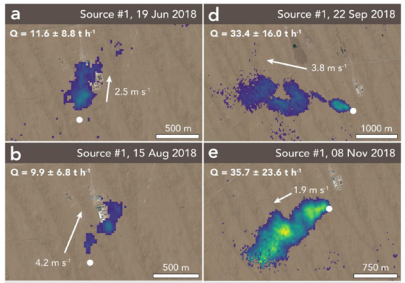
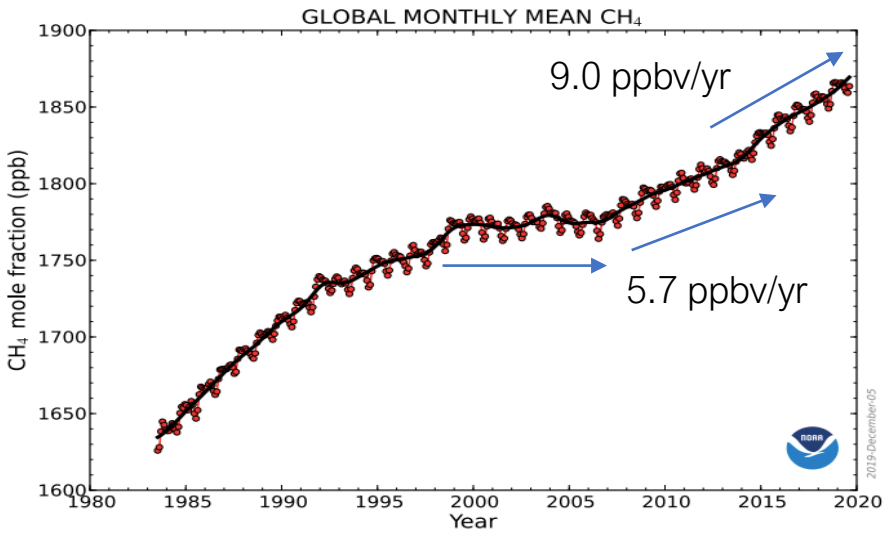


Varon et al. (2019)

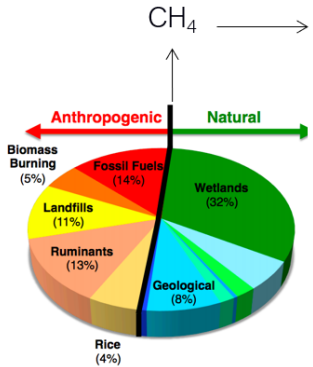
10 m resolution

What drives the increase of methane concentration?
什么因素驱动了甲烷大气浓度的上升?

CH_4 concentration in last 35 years



Atmospheric methane budget



Sink
Lifetime of 10 yrs

Tropospheric OH 89%

Soil Absorption

Stratospheric Loss

Tropospheric Cl

Sources
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What drives the increase of methane concentration?
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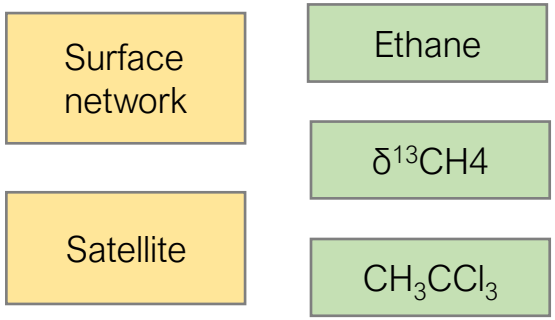
Atmospheric observations



Theories proposed to explain 2007 regrowth

Rice et al.	PNAS	Fossil fuel
Hausmann et al.	ACP	Oil and gas production
Nisbet et al.	Global Biogeochemical Cycles	Wetland or agriculture
Schaefer et al.	Science	Wetland or agriculture
Rigby et al.	PNAS	OH
Turner et al.	PNAS	OH
Worden et al.	Nature Communications	Fossil fuel; Less BM burning

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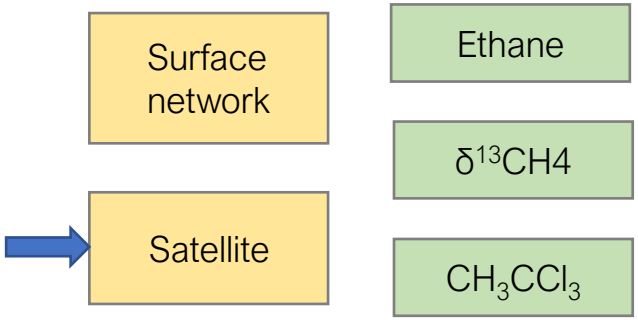

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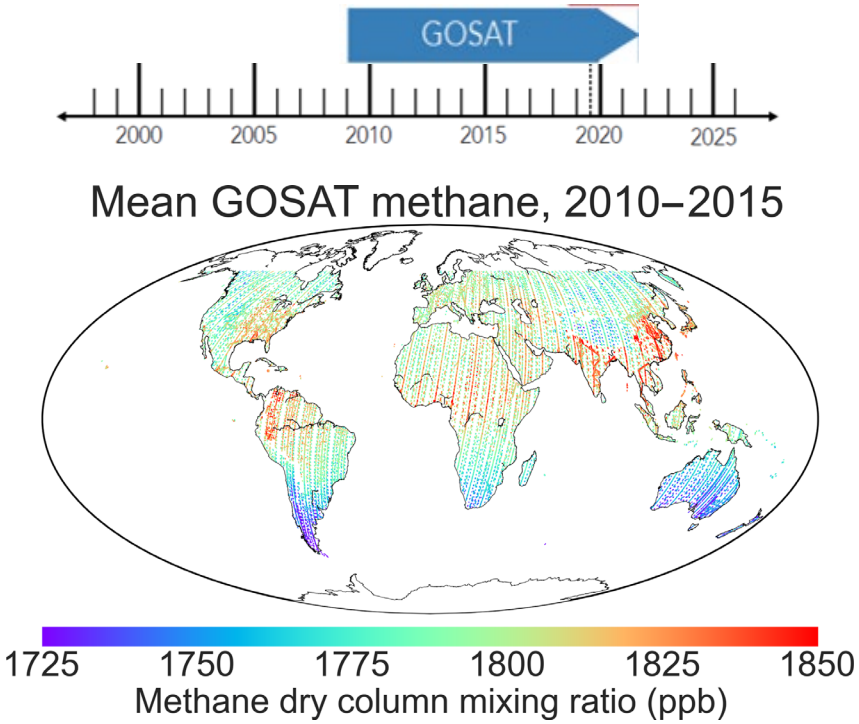
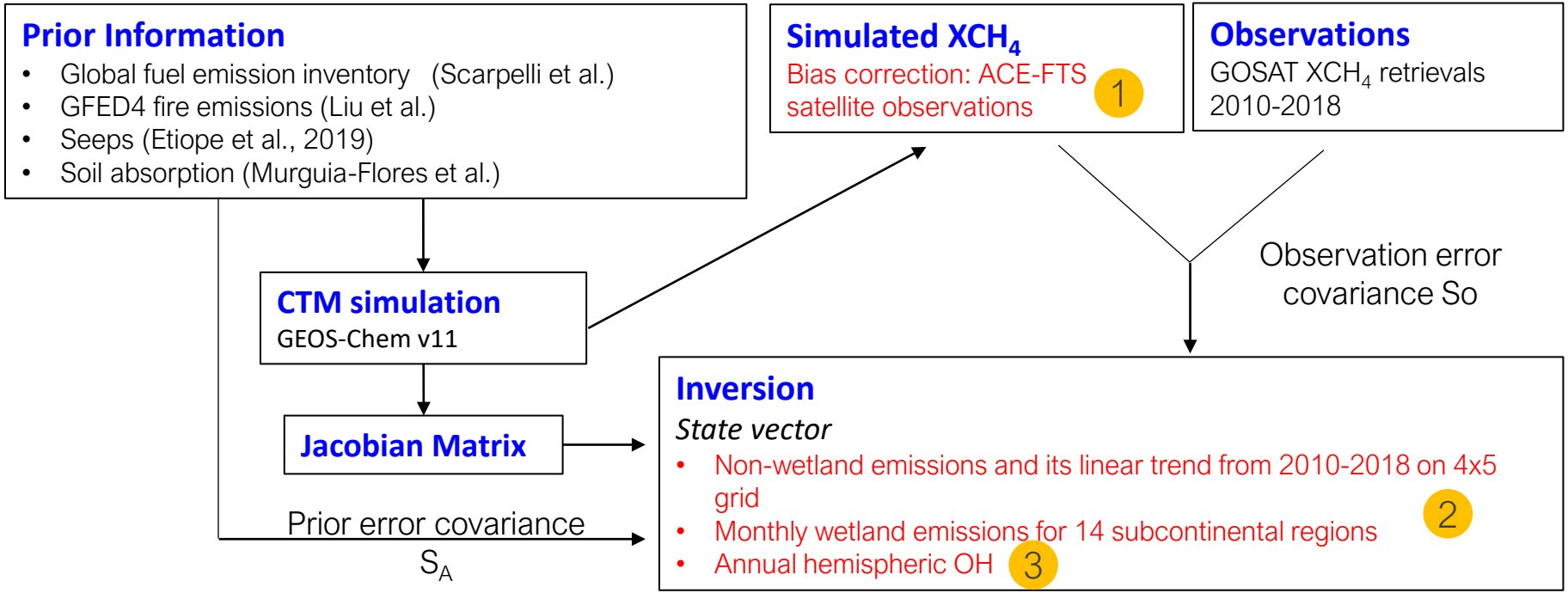
Satellite observations 卫星观测



Maasakkers et al., ACP, 2019

Inverse analysis of satellite observations 卫星数据的反演分析



Zhang et al., ACPD, 2020

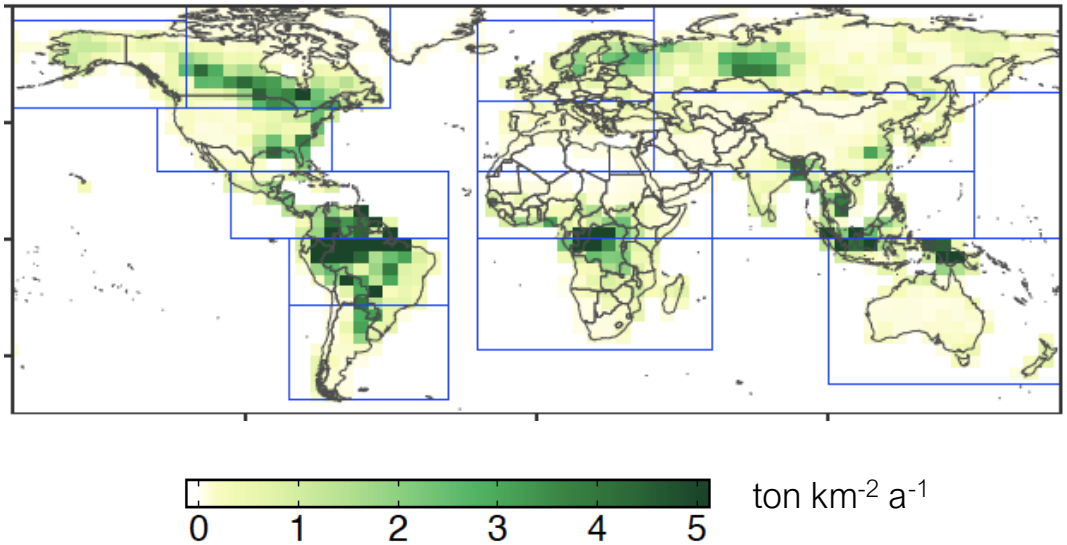
Improvements: wetlands 反演算法的改进：湿地源 2

Inversion is performed on each 4x5 grid cells for annual-mean **non-wetland** emissions and linear trend

… and **14 subcontinental** regions for **monthly**-mean wetland emissions

Superimpose the spatial correlation within a region

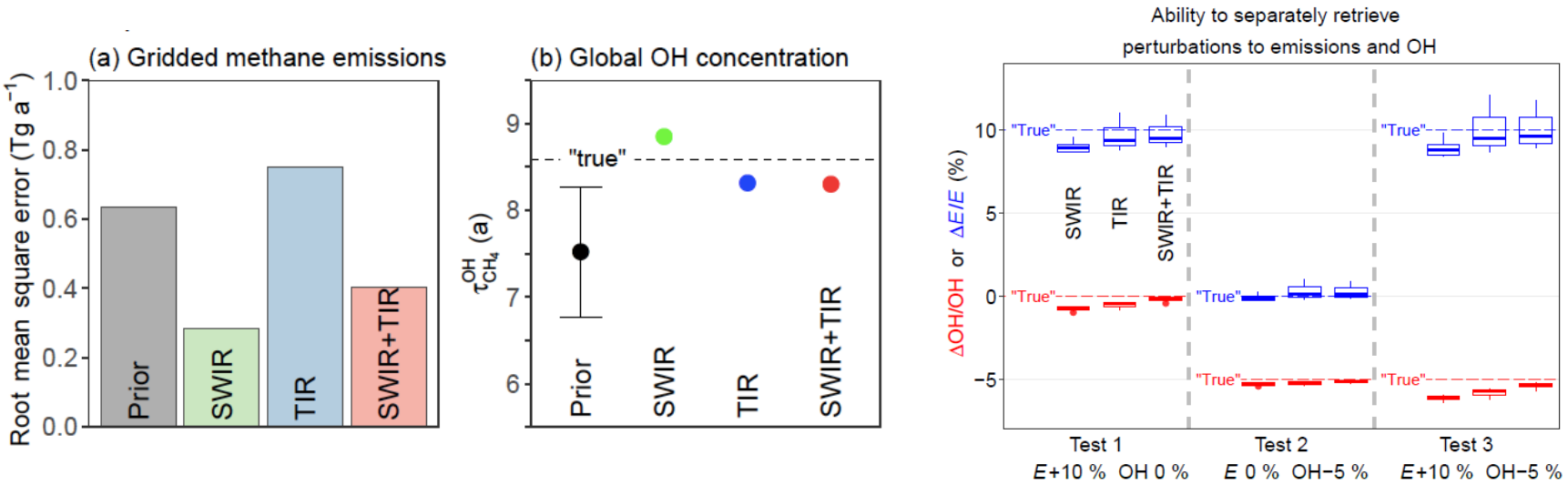
Allow for seasonality correction



Improvements: OH 反演算法的改进：OH汇

3

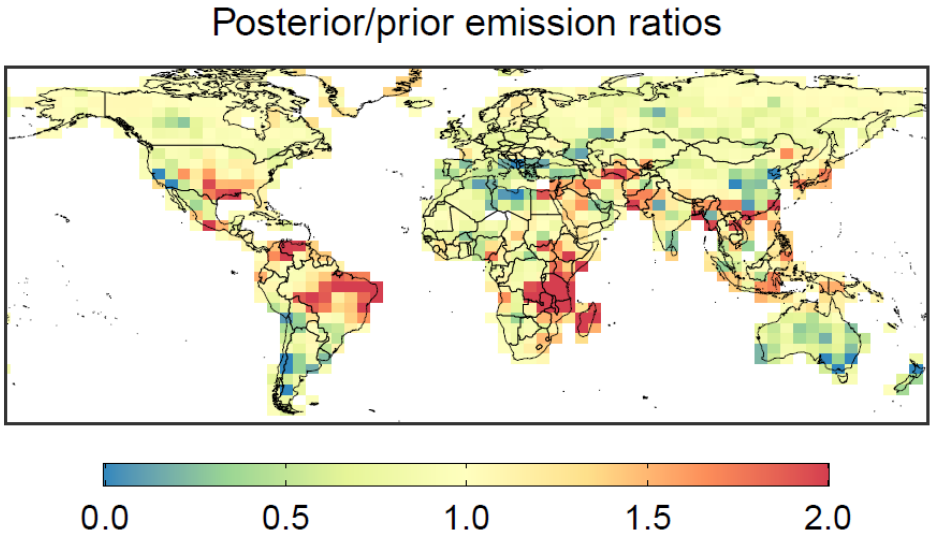
Joint optimization of methane emissions and global OH



Zhang et al., ACP, 2018

Inversion result 反演分析结果

Anthropogenic emissions



0=no information from obs.
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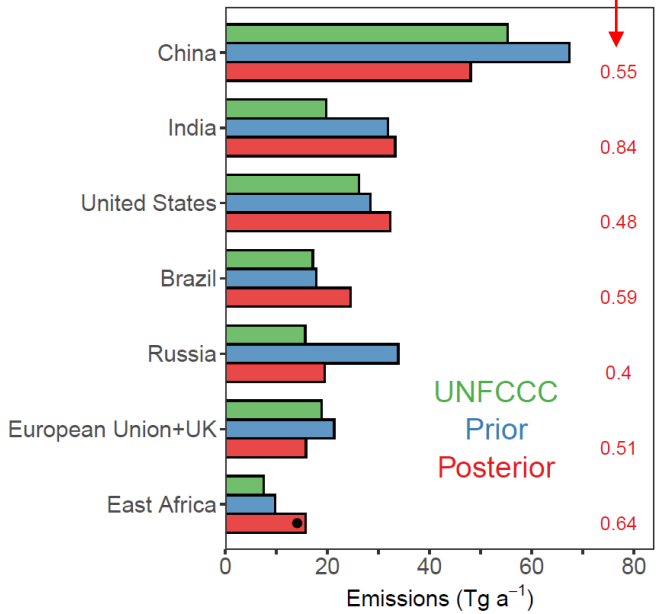
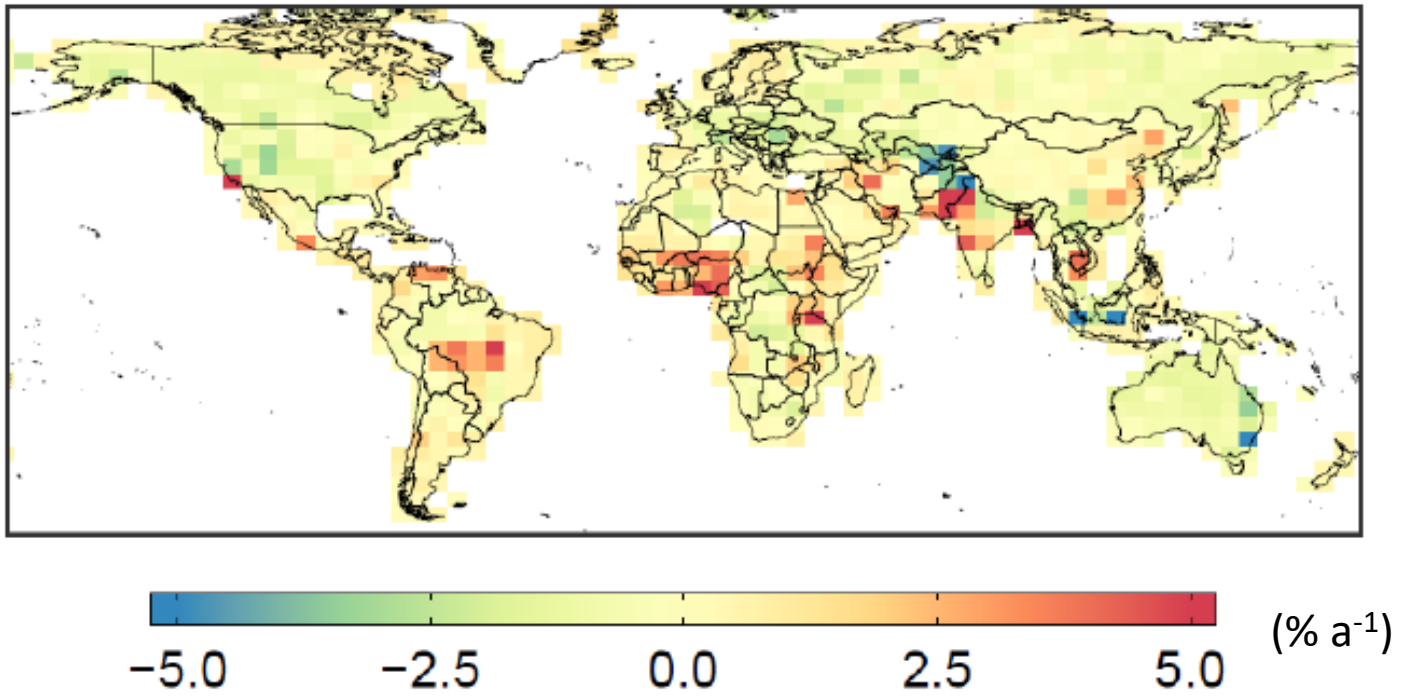


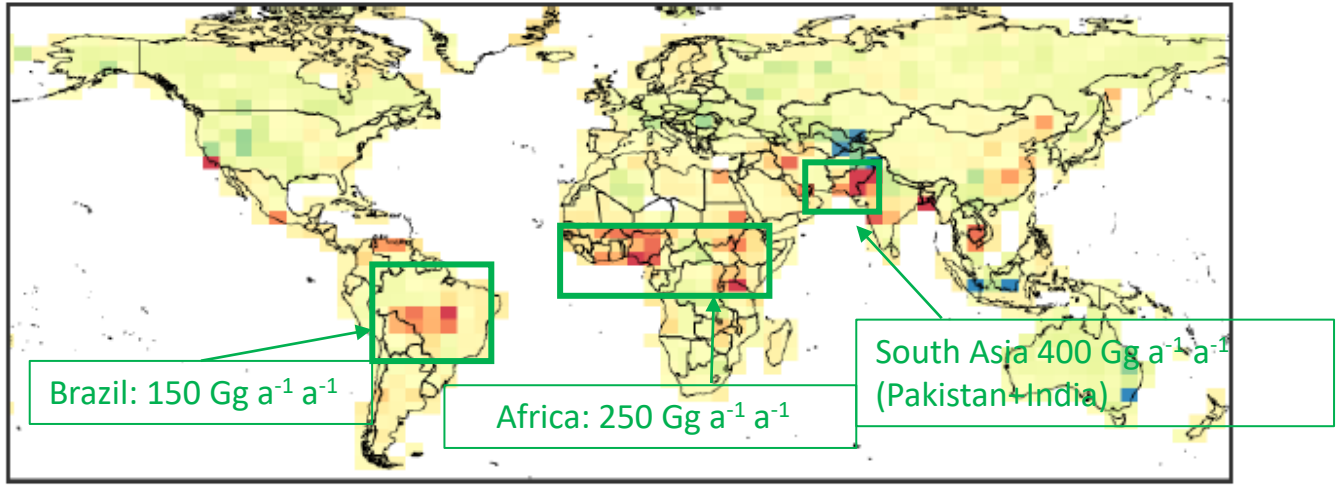
Zhang et al., ACPD, 2020

Inversion result 反演分析结果

2010-2018 Anthropogenic emission trends



Zhang et al., ACPD, 2020



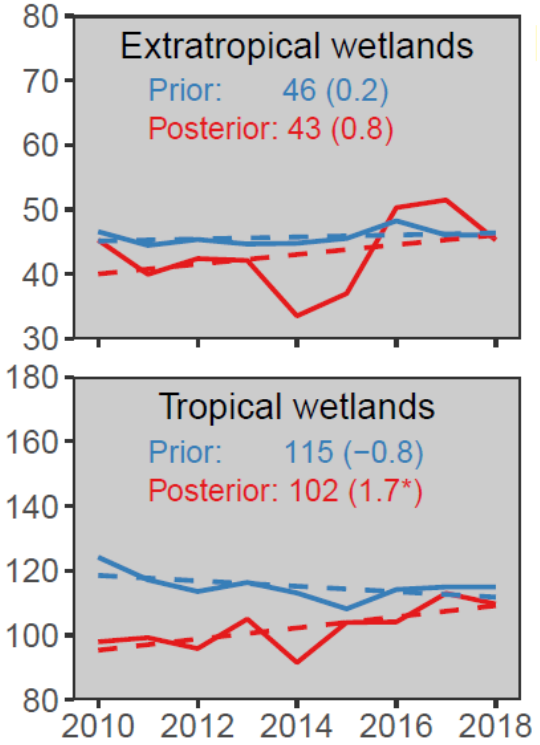
Top 5 counties with fastest growing cattle population

UNFAO

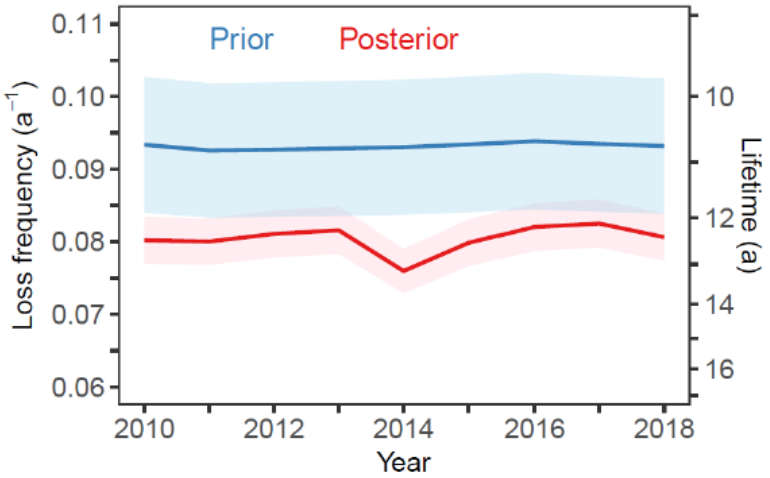
Country	Trend (million head per year)
Pakistan	1.4
Ethiopia	1.2
Tanzania	1.1
Brazil	0.9
Argentina	0.7

Inversion result 反演分析结果

Wetland emissions



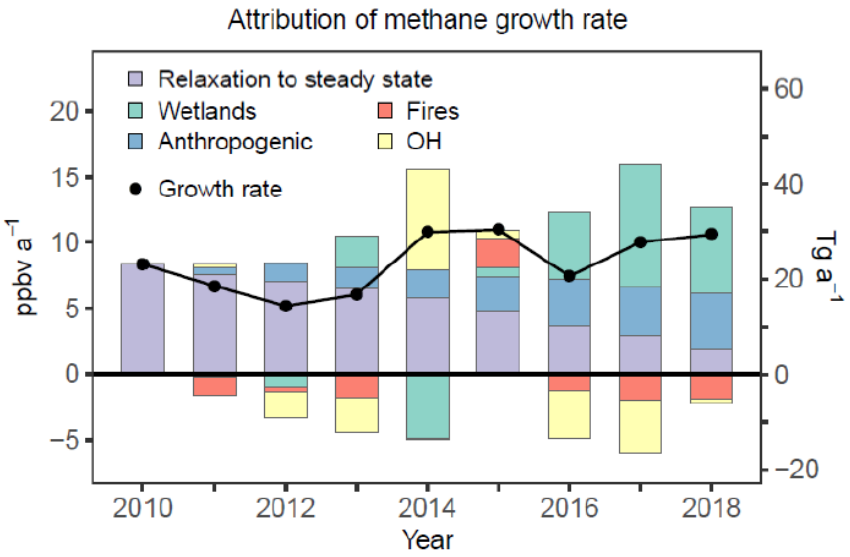
Global OH concentration



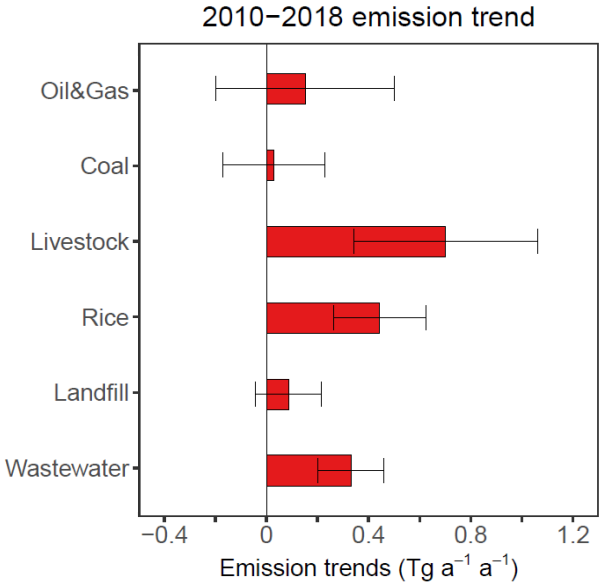
Zhang et al., ACPD, 2020

Attribution of changes in global methane budget, 2010-2018
2010-2018年全球甲烷收支变化的归因

Attribution of annual growth rate



Attribution of anthropogenic trends



Zhang et al., ACPD, 2020

Complementarity of satellite and ground observations
卫星和地面观测的互补性

Information content

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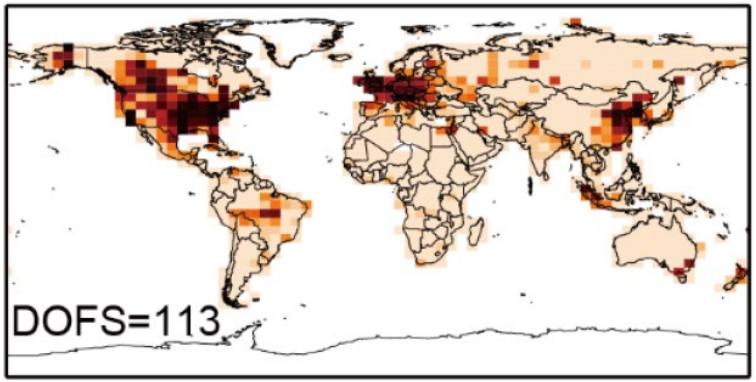
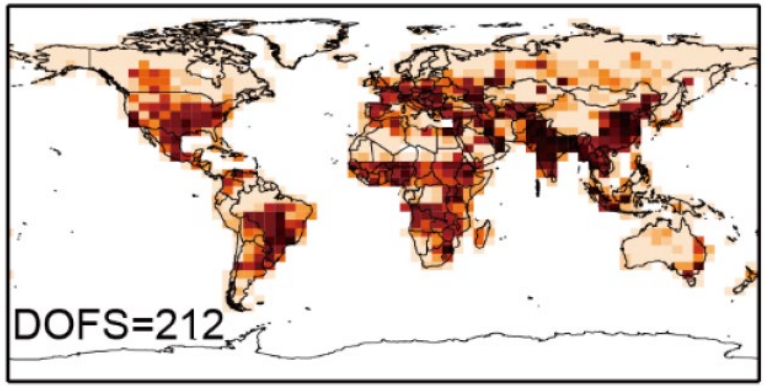
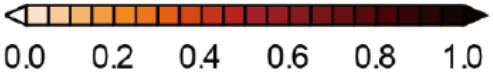
Ground network (Obspack)



Satellite observations (GOSAT)



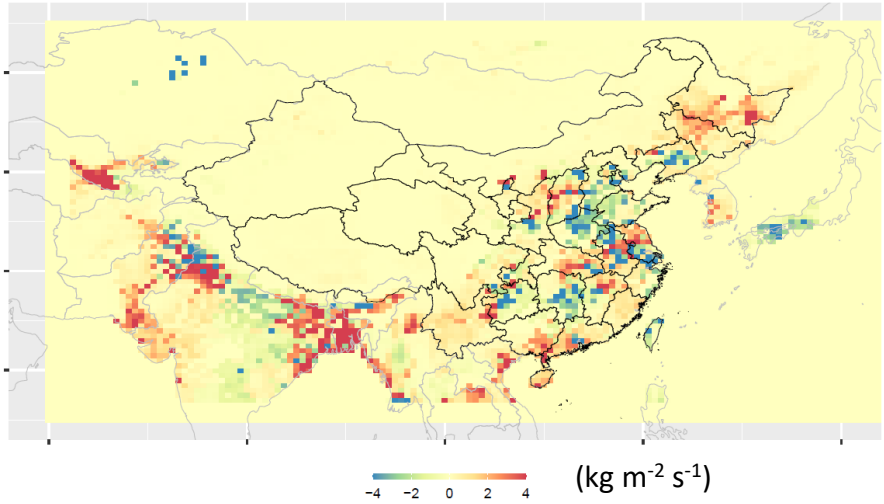


Lu et al., ACPD, 2020

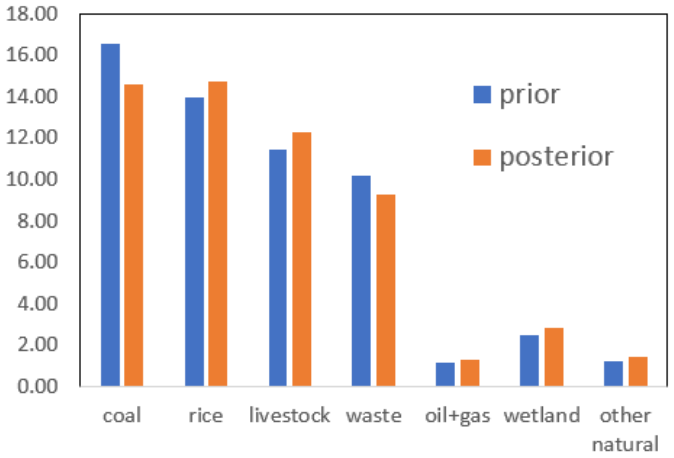
High resolution regional inversion 高分辨率区域反演

Preliminary results for China

Mean emissions 2010-2017: Posterior - Prior

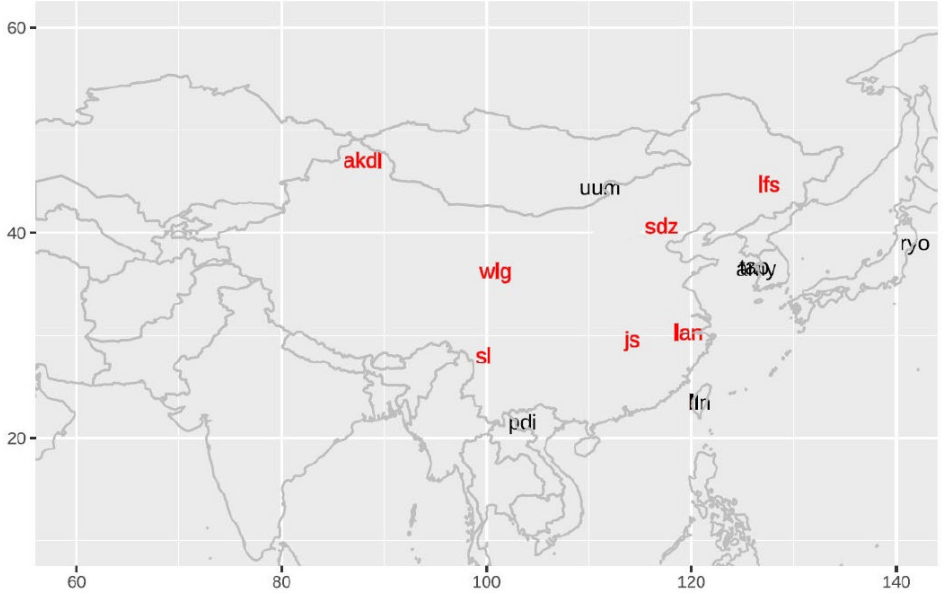


Sectoral breakdown



联合卫星和地面观测 Combine satellite and surface observations

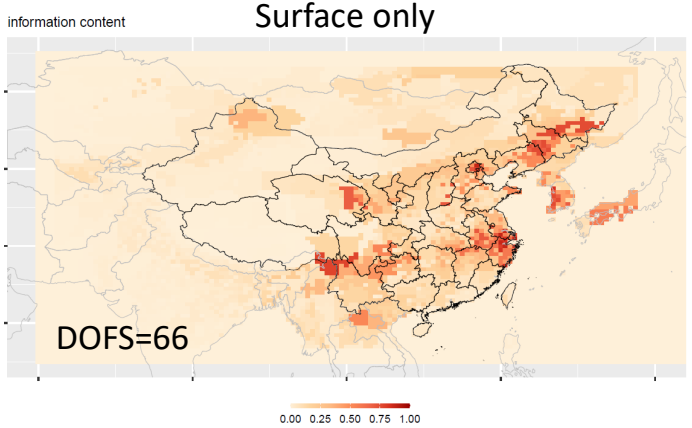
中国及周边长期观测地面站点



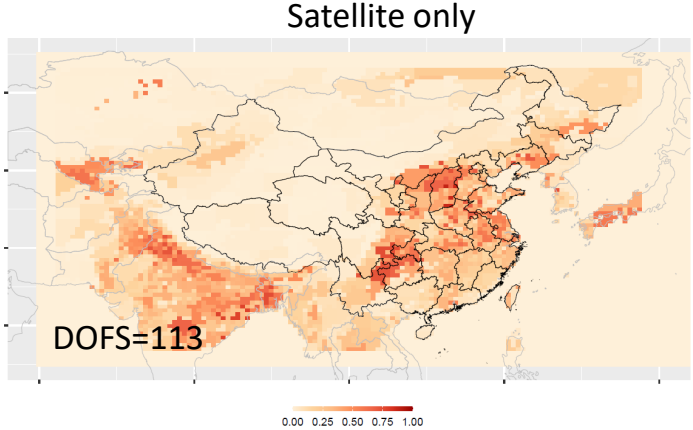
Site	Code	Lon	Lat	Alt (m)	
临安	LAN	119.73	30.3	138.6	Hourly in situ (PICARRO)
瓦里关	WLG	100.9	36.28	3816	Hourly in situ (PICARRO)
龙凤山	LFS	127.6	44.73	330.5	Hourly in situ (PICARRO)
香格里拉	SL	99.73	28.02	3580	Hourly in situ (PICARRO)
上淀子	SDZ	117.12	40.65	293.3	Hourly in situ (PICARRO)
阿克达拉	AKDL	87.93	47.10	562	Weekly flask
金沙	JS	114.22	29.63	750	Weekly flask
韩国	AMY	126.33	36.539	128.0	Hourly In situ
日本	RYO	141.82	39.032	280.0	Hourly In situ
越南	PDI	103.52	21.573	1478.0	Hourly In situ
韩国	TAP	126.13	36.738	21.0	Weekly flask
中国台湾	LLN	120.87	23.470	2867.0	Weekly flask
蒙古	UUM	111.10	44.452	1012.0	Weekly flask

Information content embedded in observations 观测蕴含的信息量

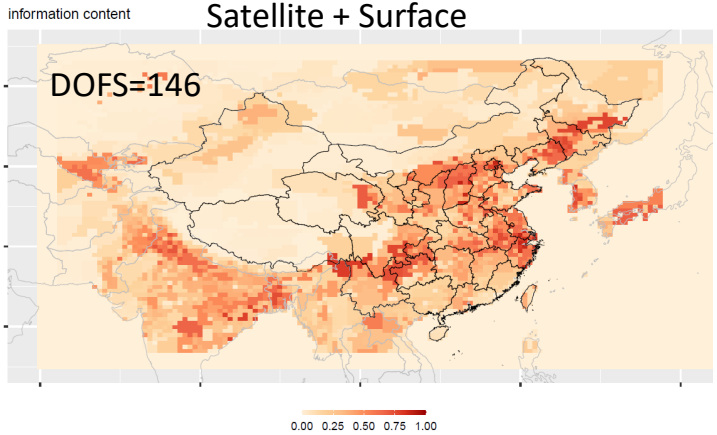
Surface only



Satellite only



Satellite + Surface



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Summary 总结

- Inversion of 2010-2018 GOSAT observations provides insight into global and regional methane budget.
  - Increasing anthropogenic emissions contribute to increasing global growth rate. Particularly, increasing livestock emissions over Southeast Asia, East Africa, and Brazil are underappreciated globally.
  - Information for seasonality and trend of regional wetland emissions
- Ground network and satellite observations provide complementary information for constraining methane emissions.