NOAA Global Monitoring Laboratory
Virtual Global Monitoring Annual Conference (eGMAC)

High Precision Greenhouse Gases Measurements in China

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21 July 2020

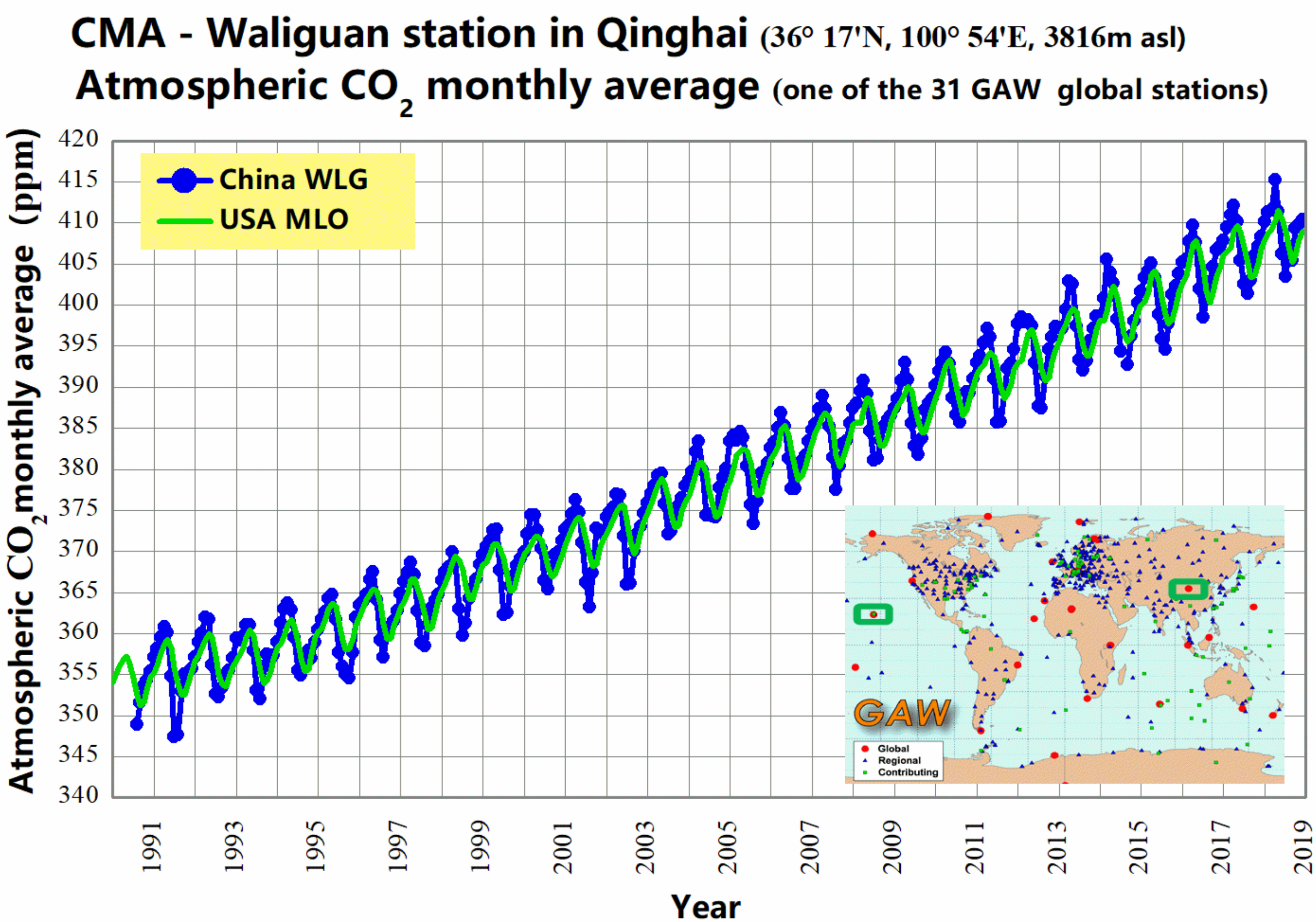
Outlines

- ✓ Long term GHG observation by CMA
- ✓ F-gas emission estimate by inverse modeling
- ✓ High precision CO_2 measurement at Beijing-Tianjin-Hebei city cluster

GHG measurement since 1990 at Mt. Waliguan

We conduct observations under the WMO/GAW program.

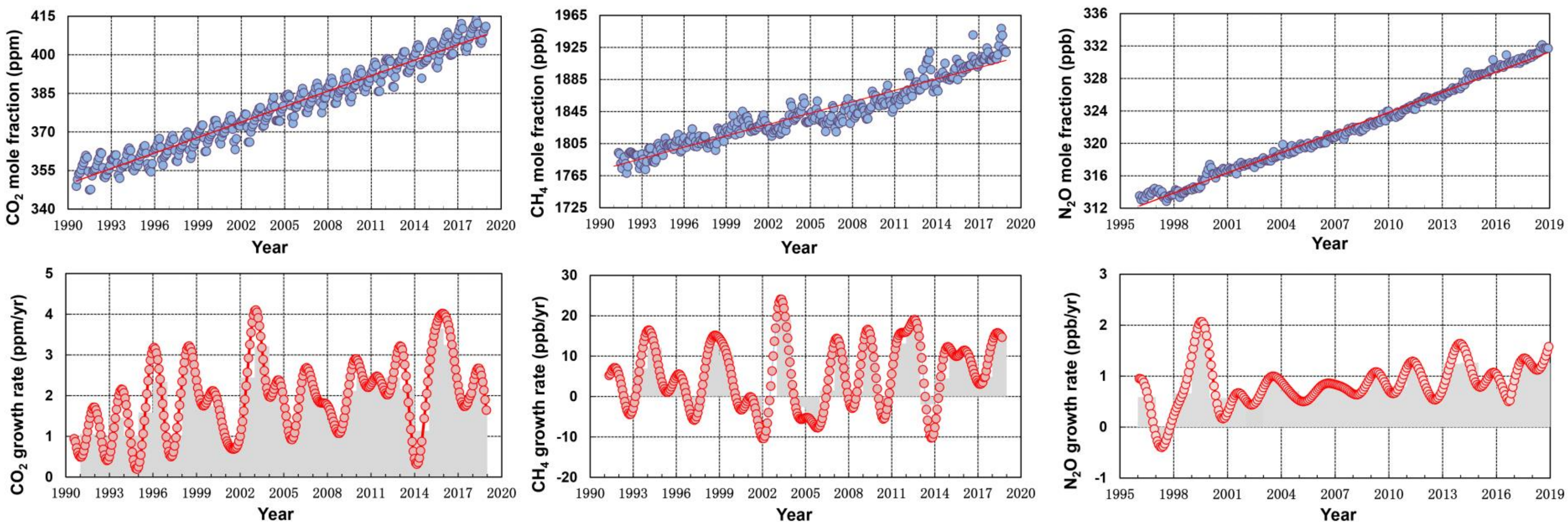
We have the longest CO_2 record in China



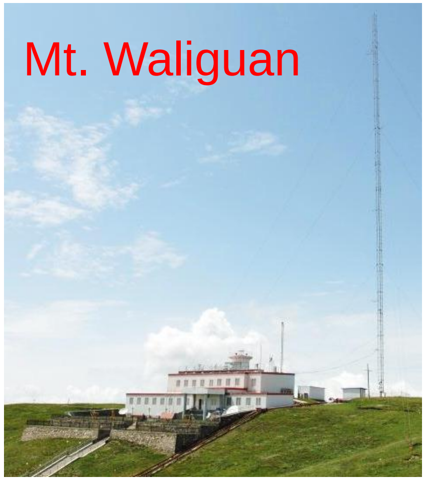
Data of MLO downloaded from WDCGG

The CO_2 and CH_4 at WLG agrees with the global average

	CO_2		CH_4		N_2O	
	Global	Waliguan	Global	Waliguan	Global	Waliguan
Mean annual mole fraction in 2018	407.8±0.1 ppm	409.4±0.3 ppm	1869±2 ppb	1923±2 ppb	331.1±0.1 ppb	331.4±0.1 ppb
2018 mole fraction relative to year 1750	147%		259%		123%	
2016-2018 absolute increase	2.3 ppm	2.4 ppm	10 ppb	12 ppb	1.2 ppb	1.1 ppb
2016-2018 relative increase	0.57%	0.59%	0.54%	0.57%	0.36%	0.33%
Mean annual absolute increase during last 10 years	2.26 ppm yr^{-1}	2.32 ppm yr^{-1}	7.1 ppb yr^{-1}	7.7 ppb yr^{-1}	0.95 ppb yr^{-1}	0.94 ppb yr^{-1}



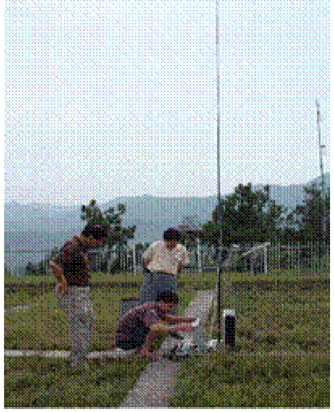
5 stations with in-situ measurement since 2010

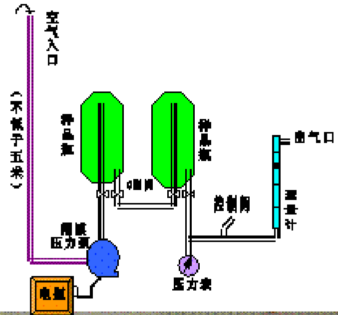


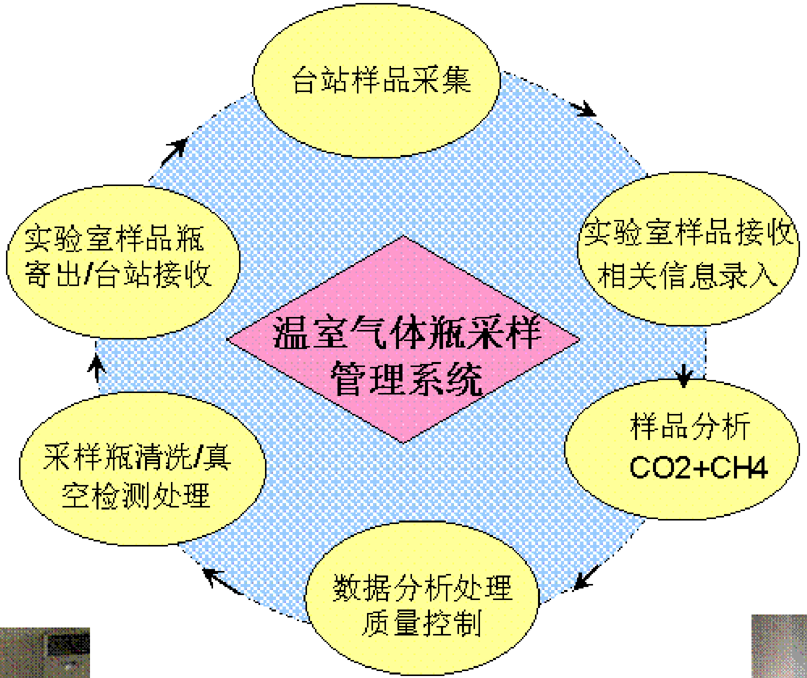
CRDS for CH_4/CO_2/CO

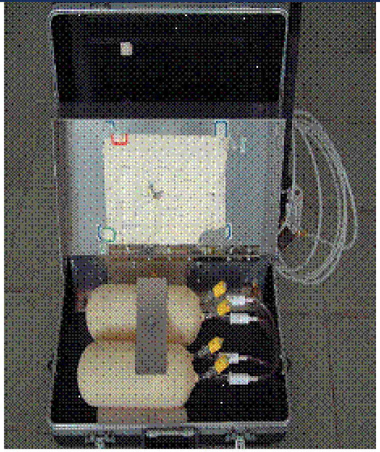
GC-FID/ECD for CH_4/CO/N_2O/SF_6

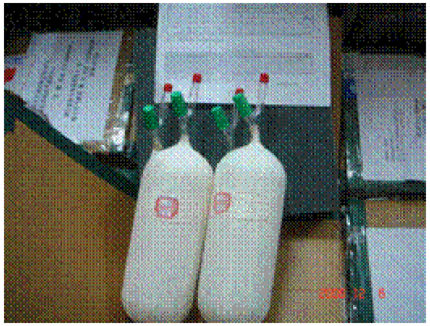
Weekly flask sampling at 7 stations since 2006











Central lab in Beijing (sample analysis + calibration)

Trace to WMO scale

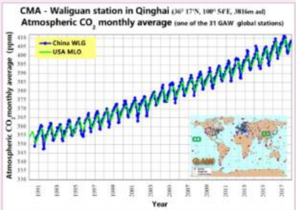
Release annual China GHG Bulletin since 2012

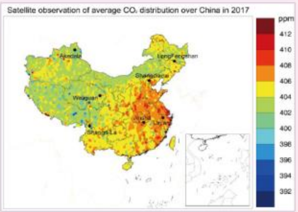
CHINA GREENHOUSE GAS BULLETIN

The State of Greenhouse Gases in the Atmosphere
Based on Chinese and Global Observations before 2017

No. 7 December 2018

Climate Change Centre
China Meteorological Administration





Since 1990s, China Meteorological Administration (CMA) has put in place seven atmospheric background stations - Waliguan in Qinghai (WLG), Shangdianzi in Beijing (SDZ), Lin'an in Zhejiang (LAN), Longfengshan in Heilongjiang (LFS), Shangri-La in Yunnan (XGL), Jinsha in Hubei (JSA) and Akedala in Xinjiang (AKD), which represent a number of typical climatic, ecological and economic zones in China. Greenhouse gases and related tracers have been observed by network stations in a standard and consistent routine in response to the Kyoto Protocol and the Montreal Protocols. On Dec. 22 2016, China launched the first carbon dioxide monitoring satellite (TanSat), which is the third satellite for CO_2 observation in the world. The upper left figure shows the monthly CO_2 mole fractions observed at the Waliguan station in Qinghai province, China and the Mauna Loa station in Hawaii, the United States of America from 1990 to 2016. The upper right figure shows the average CO_2 distribution from satellite observation over the land area of China in 2017.

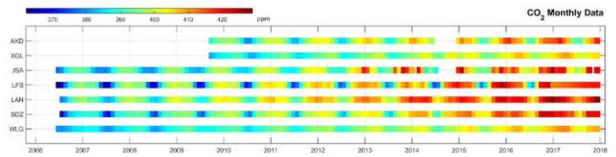
Executive summary

The World Meteorological Organization (WMO) Greenhouse Gas Bulletin (2017) No. 14 released by WMO on 22 November 2017 shows that globally averaged mole fractions in atmospheric carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) continued to hit new highs in 2017, with CO_2 at 405.5 ± 0.1 [1] ppm [2], CH_4 at 1859 ± 2 ppb ppb[3] and N_2O at 329.9 ± 0.1 ppb. These values constitute 146%, 257% and 122% of pre-industrial (before 1750) levels.

As analyzed from observational data at the Waliguan station in Qinghai through 2017, averaged mole fractions in atmospheric CO_2, CH_4 and N_2O also hit new highs, registering 407.0 ± 0.2 ppm for CO_2, 1912 ± 2 ppb for CH_4 and 330.3 ± 0.1 ppb for N_2O. As a record high since the observation was started in 1990, they are roughly equivalent to the averaged mole fractions in the northern mid-latitudes, but are slightly higher than the global averages in all these components over the same period. Global mole fractions in atmospheric CO_2, CH_4 and N_2O increased by 2.2 ppm, 7 ppb and 0.9 ppb in absolute terms, from 2016 to 2017, while those at Waliguan by 2.6 ppm, 5 ppb and 0.6 ppb. Global annual averages in atmospheric CO_2, CH_4 and N_2O over the past 10 years increased by 2.24 ppm, 6.9 ppb and 0.93 ppb in absolute terms, while those at Waliguan 2.28 ppm, 7.0 ppb and 0.92 ppb.

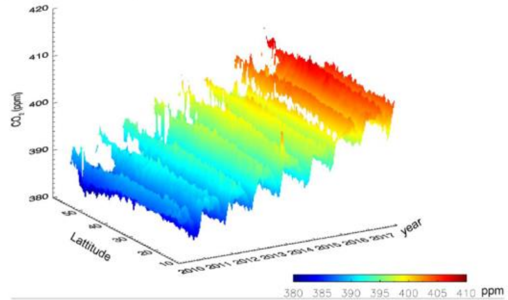
In 2017, valid monthly atmospheric CO_2, CH_4 and N_2O mole fractions at the 6 regional stations (Shangdianzi in Beijing, Lin'an in Zhejiang, Longfengshan in Heilongjiang,

CO_2 is the most important anthropogenic GHGs in the atmosphere, accounting for ~65%[5] of the total radiative forcing by long-lived GHGs. Before the industrial revolution (1750), the globally averaged mole fraction of atmospheric CO_2 was maintained at ~ 278 ppm. Anthropogenic sources include fossil fuel and biomass combustion, land-use change, etc. The globally averaged and the Waliguan averaged mole fractions of atmospheric CO_2 in 2017 stood at 405.5 ± 0.1 and 407.0 ± 0.2 ppm, with the mean annual absolute increases during last 10 years at 2.24 ppm and 2.28 ppm. In 2017, the values for Shangdianzi, Lin'an, Longfengshan, Shangri-La, Jinsha, and Akedala station were 416.0 ± 1.8 ppm, 419.5± 1.9 ppm, 415.6 ± 0.8ppm, 404.8 ± 0.9 ppm, 412.3 ± 3.0 ppm, and 407.4 ± 2.9 ppm, respectively, with valid monthly CO_2 mole fractions were apparently higher than the respective month in the previous year.



Monthly mean mole fractions of atmospheric CO_2 in the last decade at seven CMA background stations

The results from satellite show that the global and China average CO_2 in 2017 were 402.2 ± 2.8 ppm and 405.0 ± 3.0 ppm respectively. The Global and China annual averages in atmospheric CO_2 increased by 2.2 ppm and 2.6 ppm in absolute terms from 2016 to 2017, which are roughly equivalent to the values over the past 8 years, 2.2 ppm and 2.4 ppm. Satellite observation also shows the average CO_2 in different areas in China, 404.0 ±2.7 ppm for North China, 408.3 ± 1.9 ppm for East China, 406.1 ± 2.0 ppm South China, 407.7 ± 1.7 ppm for Central China, 403.5 ± 2.7 ppm for Northeast China, 404.6 ± 3.0 ppm for West China. Among them, the average CO_2 in East China, South China and Central China are higher than the value in whole China. The average CO_2 in East China shows the highest value.

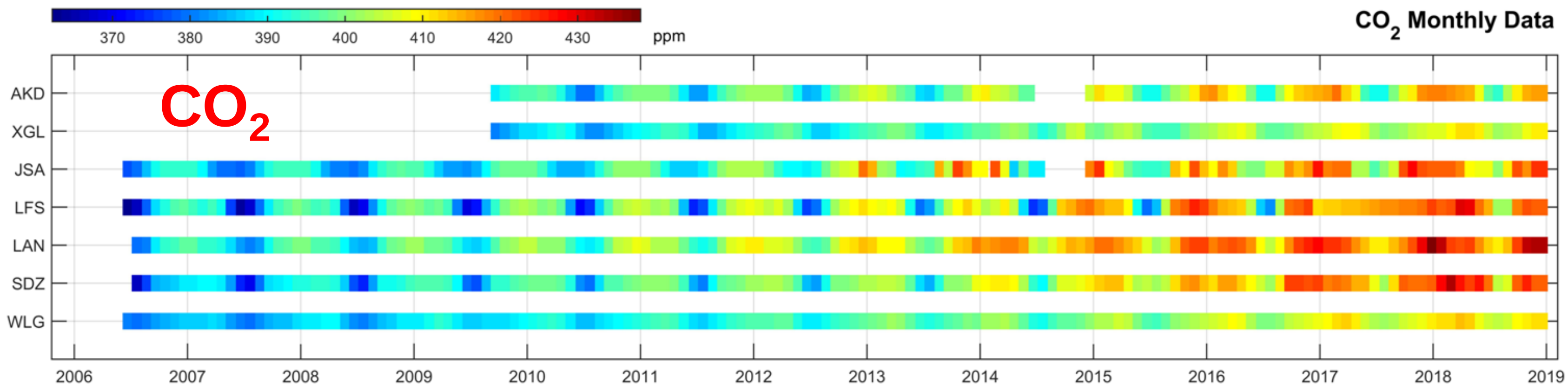


Satellite observation of monthly average CO_2 variation in different latitude over China from 2010 to 2017

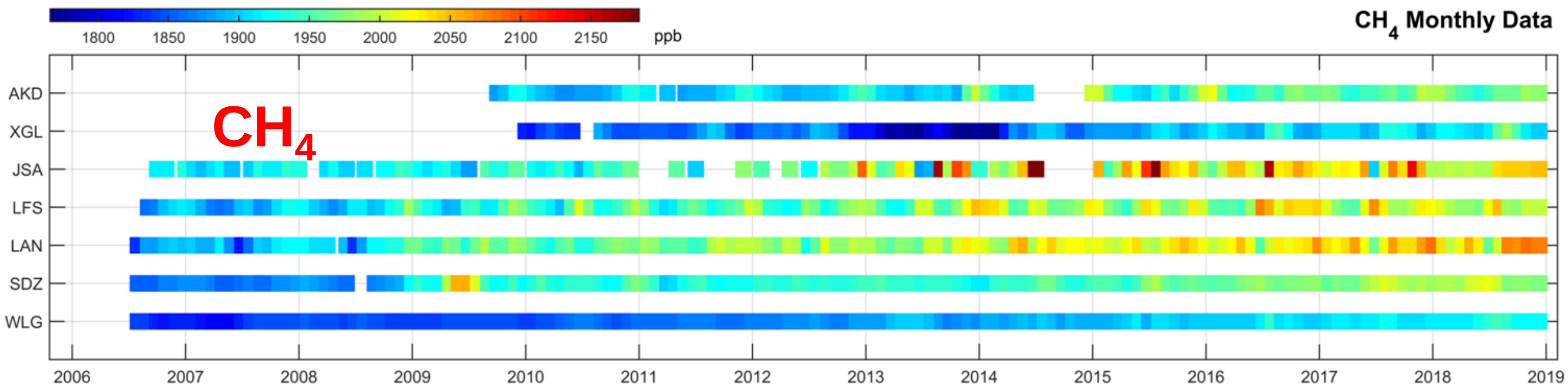
Methane (CH_4)

Concentrations of CO_2/CH_4/N_2O/SF_6/HFCs of 7 CMA stations

CO_2 and CH_4 mixing ratios of 7 CMA stations since 2006



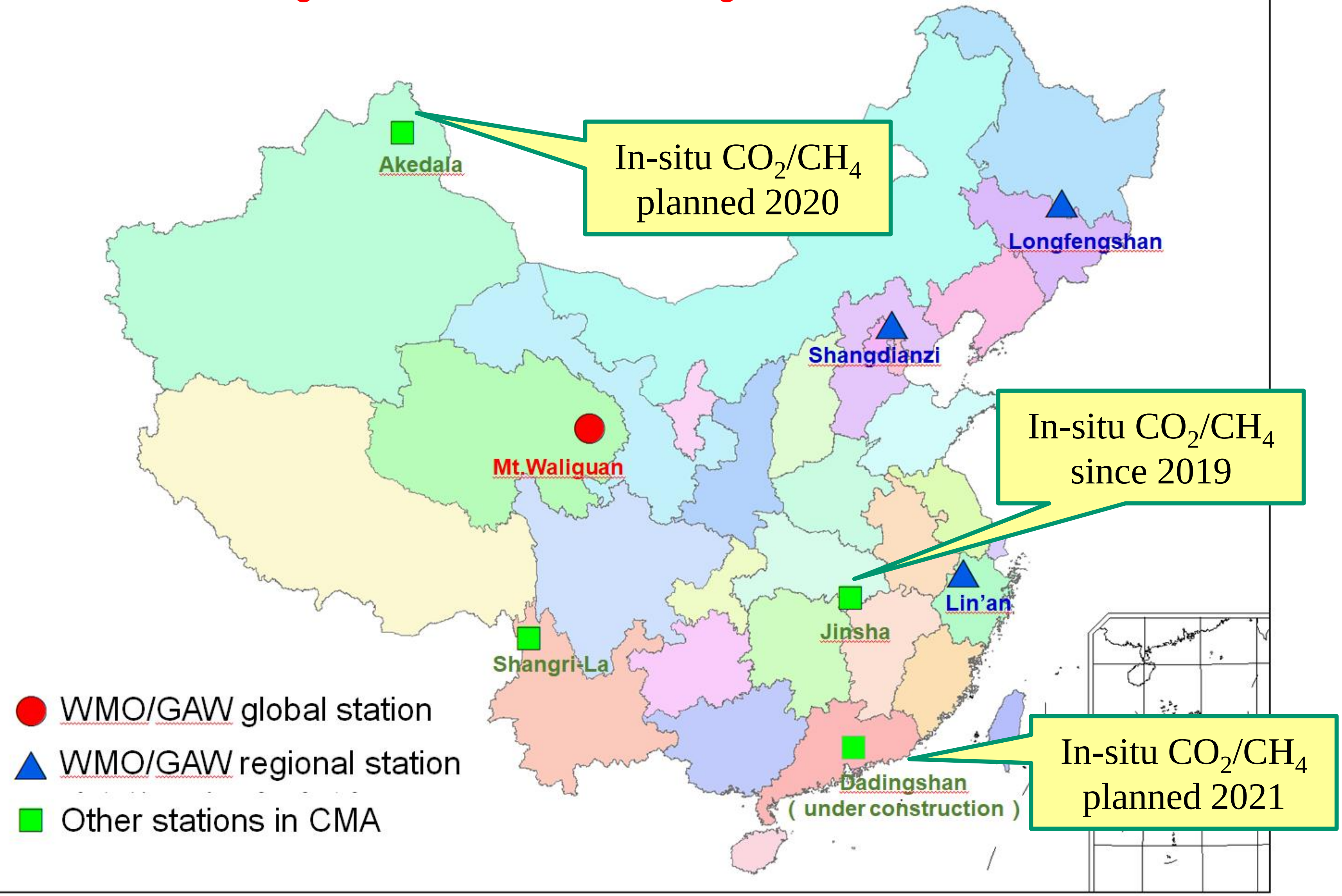
Monthly mean mole fractions of atmospheric CO_2 in the last decade at seven CMA background stations



Monthly mean mole fractions of atmospheric CH_4 in the last decade at seven CMA background stations

Update of CMA GHG network

1 WMO/GAW global + 3 WMO/GAW regional +4 National stations



Chinese GHGs observation network

China Meteorological Administration

Background stations (8 stations)

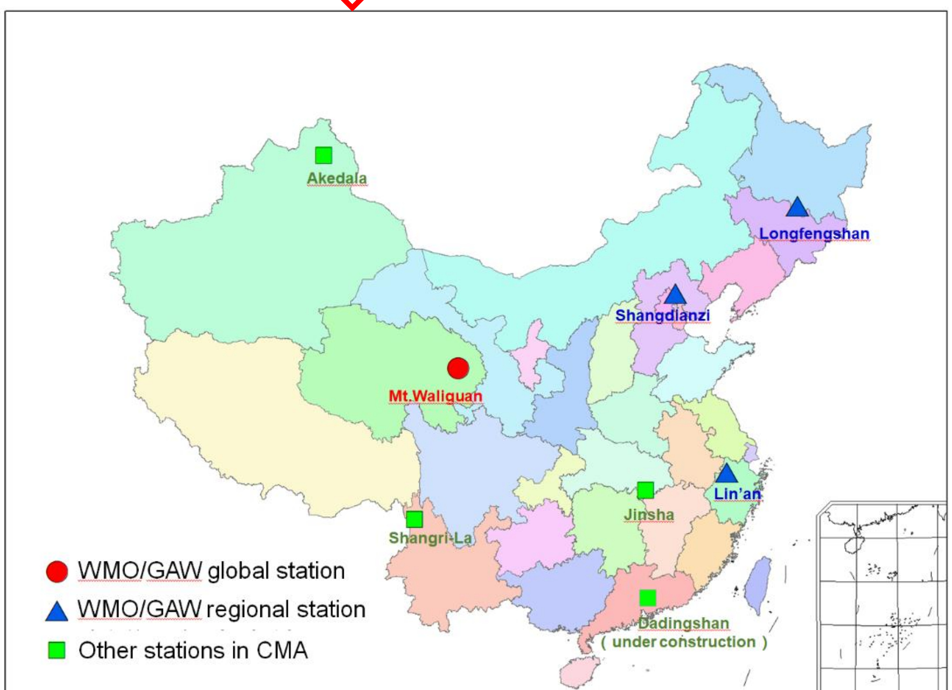
Provincial bureau (33 stations)

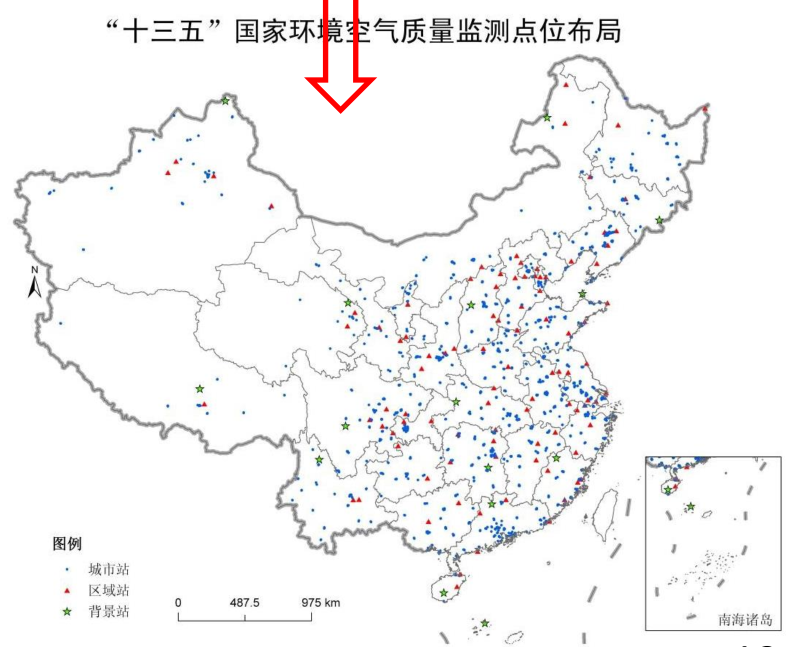
Ministry of Ecology and Environment of the P. R. C.

Background stations (16 stations)

Provincial bureau (>30 stations)

MEE has led climate change since 2018

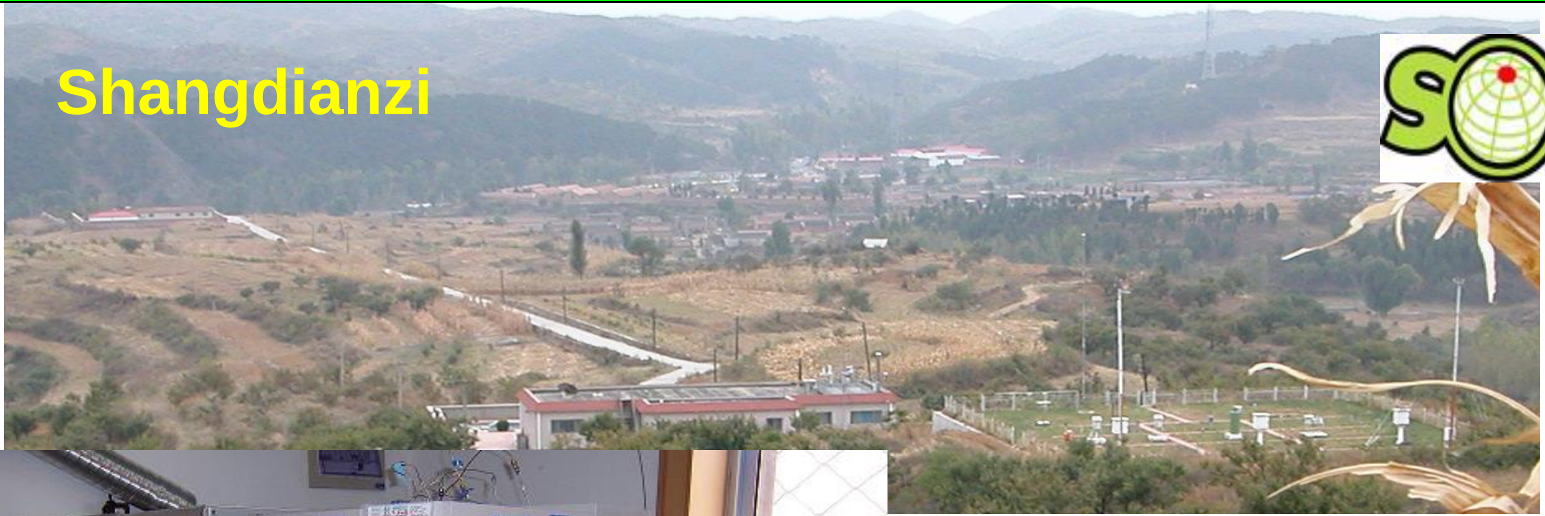


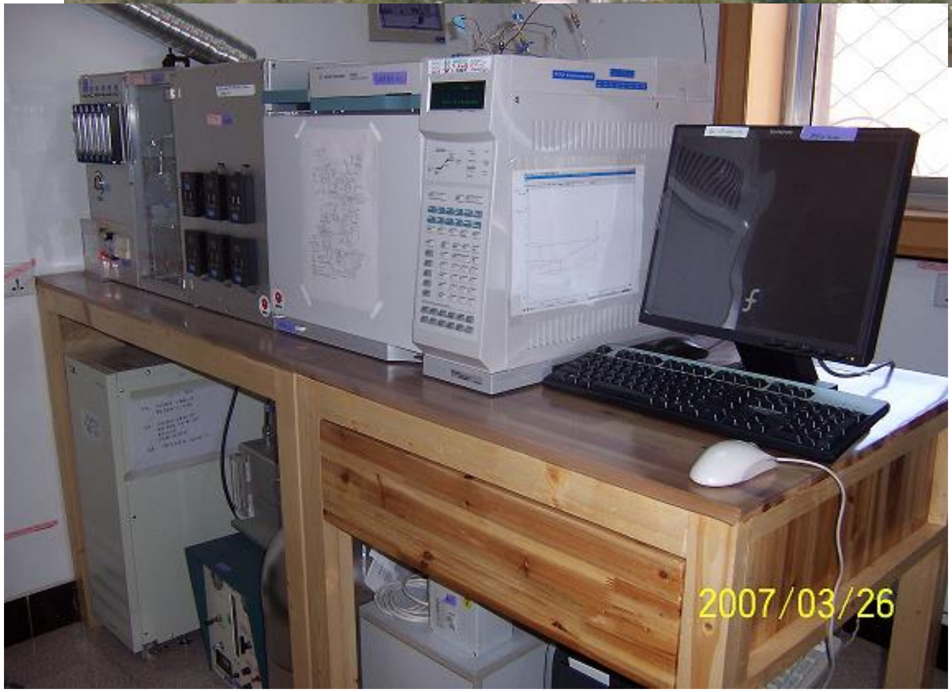


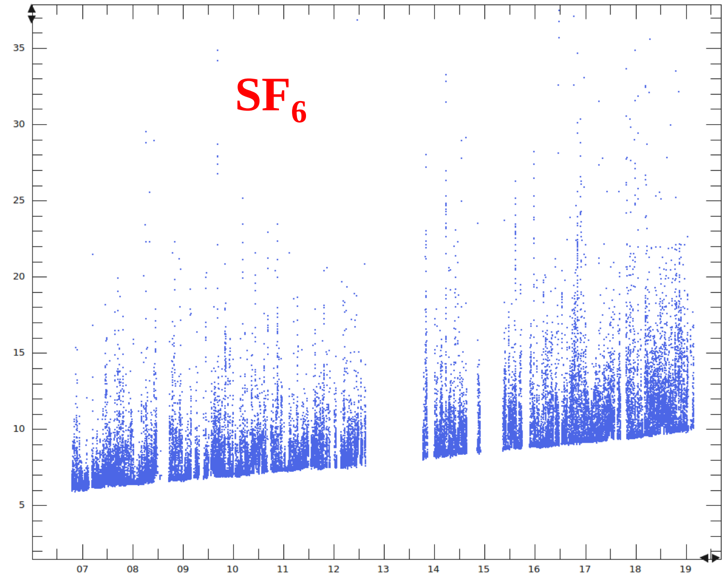
Outlines

- ✓ Long term GHG observation by CMA
- ✓ F-gas emission estimate by inverse modeling
- ✓ High precision CO_2 measurement at Beijing-Tianjin-Hebei city cluster

SF_6 in-situ measurement by GC-ECDs since 2006 at Shangdianzi Station

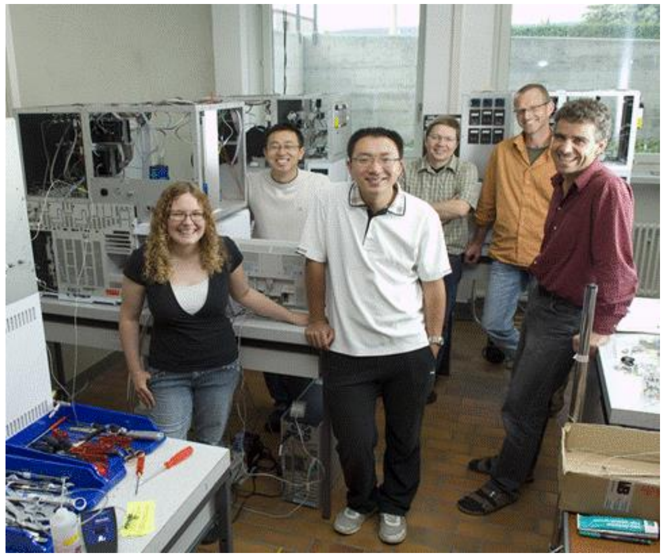






HFC+PFC measurement since 2010
NF_3 measurement since 2016

AGAGE



Medusa technique developed by AGAGE

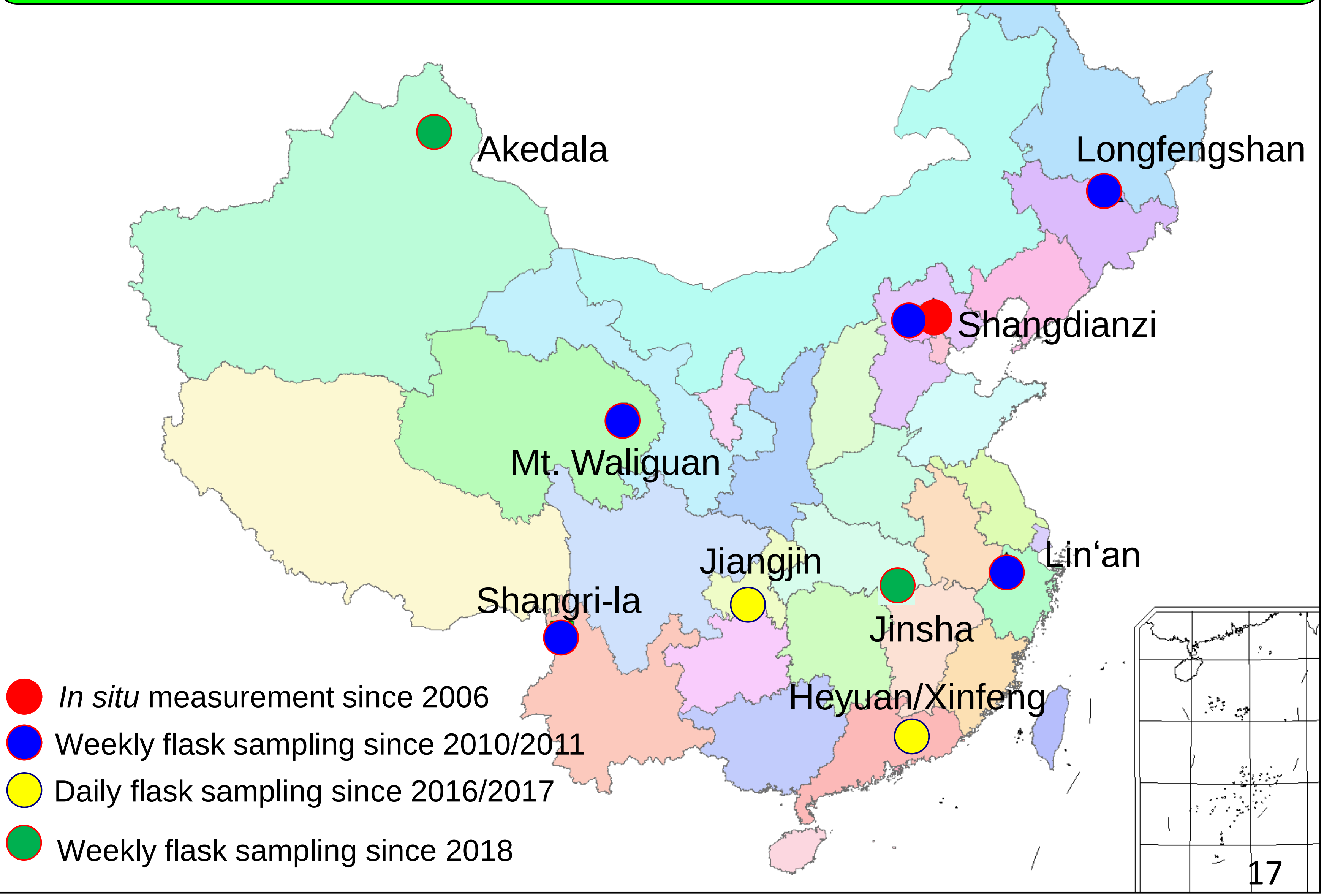
Observed GHG compounds

- **CO_2**
- **CH_4**
- **N_2O**
- **HFCs: Hydrofluorocarbons**

  HFC-32 HFC-23
  HFC-125 HFC-134a
  HFC-152a HFC-227ea
  HFC-143a HFC-236fa
  HFC-365mfc HFC-245fa
  HFC-43-10mee
- **PFCs: Perfluorocarbons**

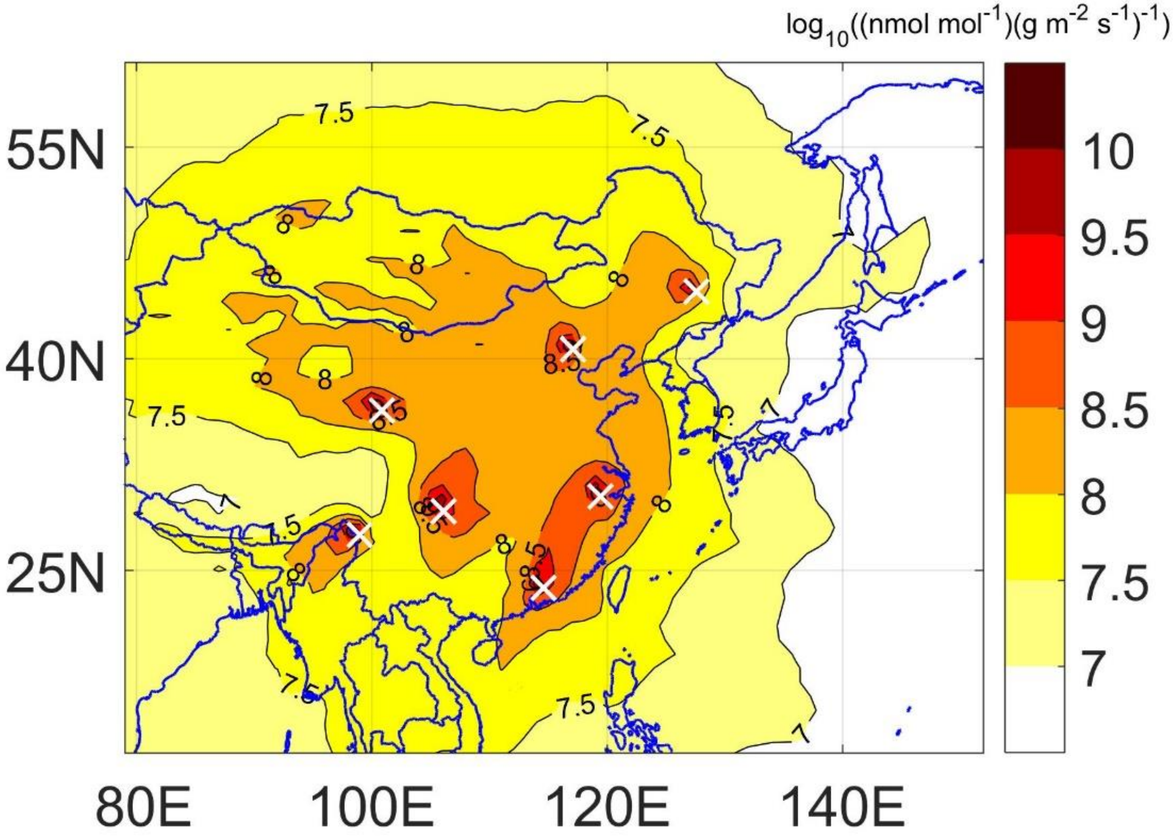
  CF_4 ***PFC-116 PFC-218***
  PFC-318 C_4F_{10} C_6F_{14}
- **SF_6**
- **NF_3**

F-gas observation network (CMA)



Footprint map

Average of seven sites in China



Seven sites have good spatial coverage for China

Emission estimate by top-down method

Prior emission field (1*1)
(constant over 2011-2017)
Roughly populated distributed

FLEXPART

Simulated mole fractions

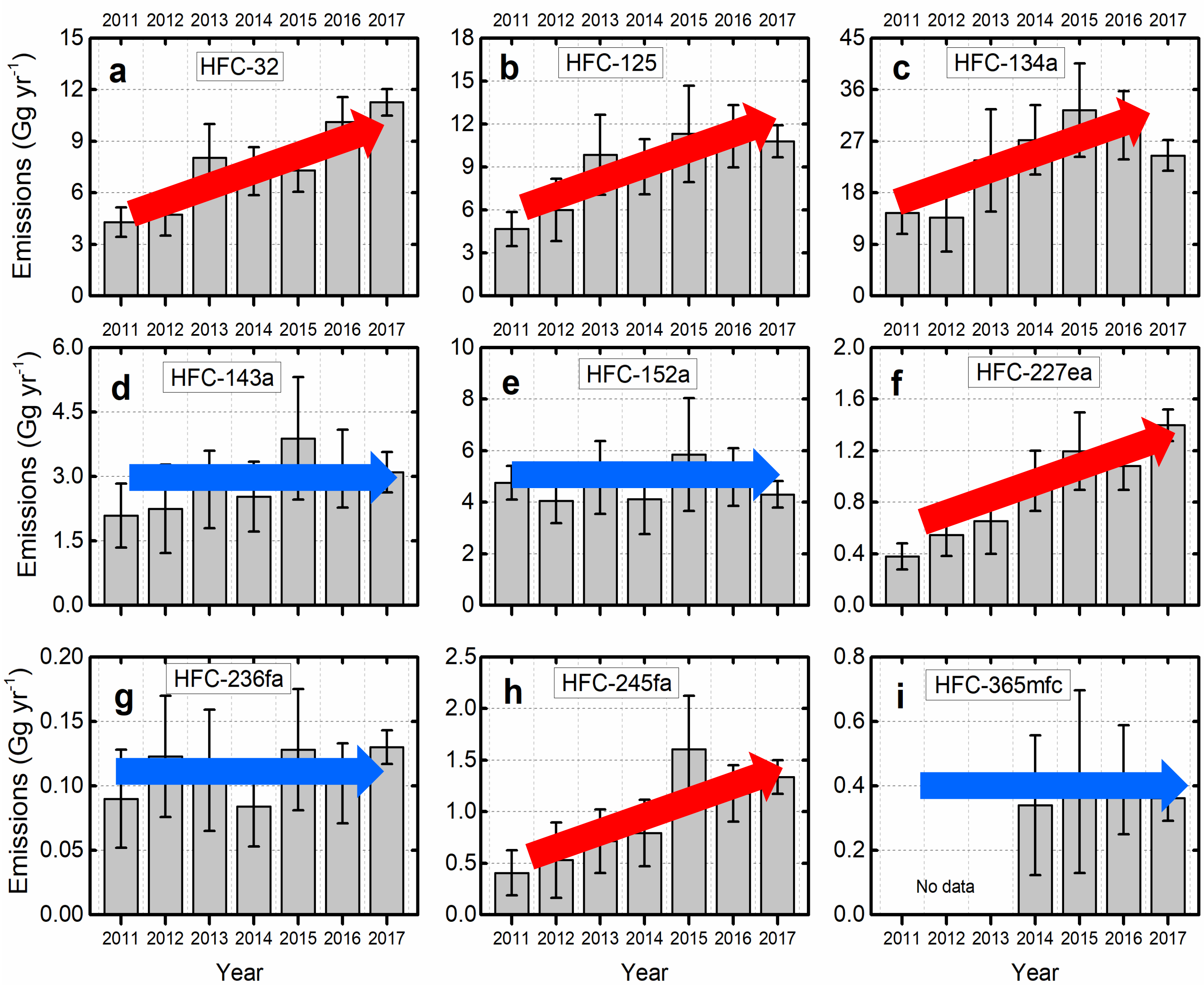
3-hourly emission sensitivity map

Observation data

Bayesian inversion

Posterior emission field (1*1)

Emissions of HFC-32, HFC-125, HFC-134a, HFC-227ea, and HFC-245fa have been increasing over 2011-2017



Compare with other studies

Environmental Science & Technology Letters
Letter
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pubs.acs.org/journal/estlcu

China's Hydrofluorocarbon Emissions for 2011−2017 Inferred from Atmospheric Measurements

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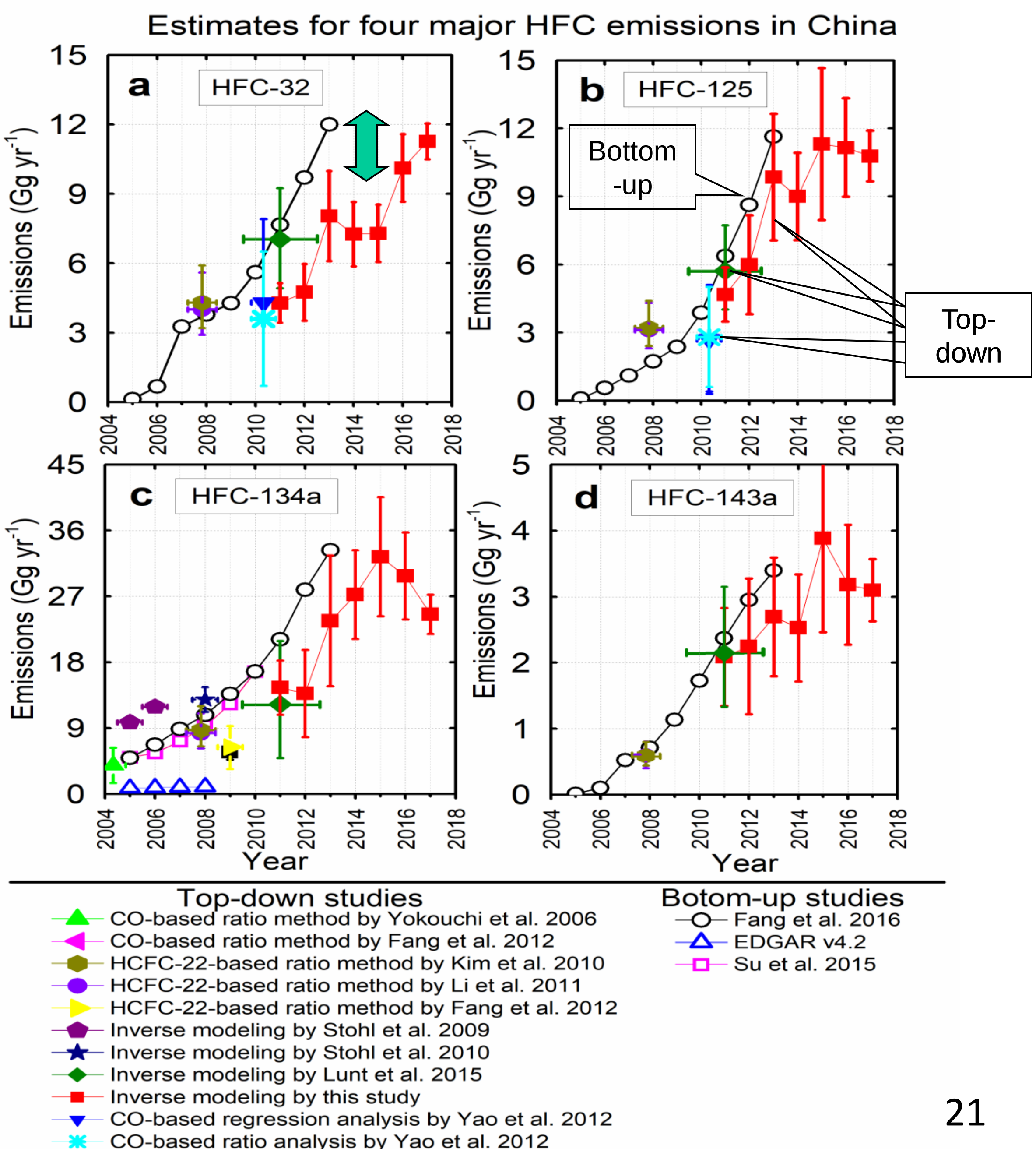
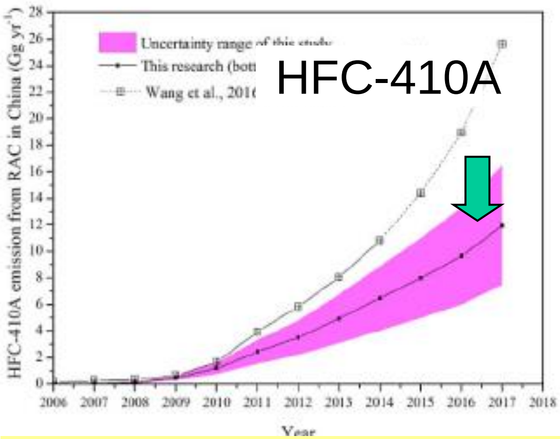
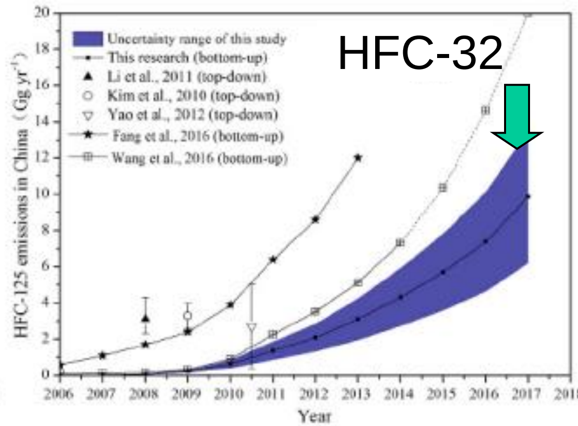
Supporting Information

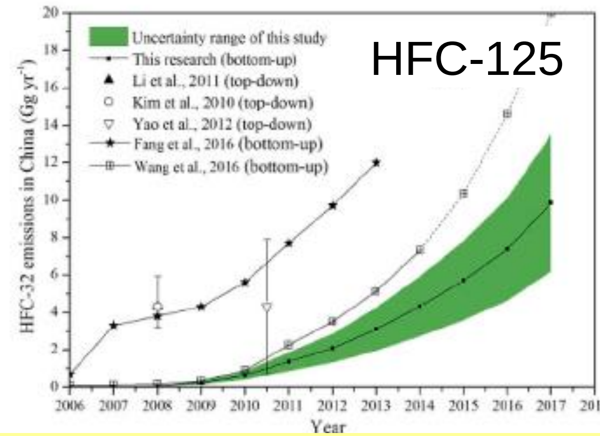
ABSTRACT: Hydrofluorocarbons (HFCs) have been widely used in China to replace ozone-depleting substances (ODSs) that must be phased out under the Montreal Protocol. Few studies have reported on HFC emissions in China, especially for recent years and using top-down approaches based on atmospheric measurements. Here we used flask and *in situ* measurements for nine HFCs from seven sites across China over the period of 2011−2017, and FLEXPART-model-based Bayesian inverse modeling, to estimate HFC emission magnitudes and changes in China. We found that emissions of HFC-32 (CH_2F_2), HFC-125 (CHF_2CF_3), HFC-134a (CH_2FCF_3), HFC-227ea (CF_3CHFCF_3), and HFC-245fa ($CHF_2CH_2CF_3$) have been increasing fast over this period while emissions of HFC-143a (CH_3CF_3), HFC-152a (CH_3CHF_2), HFC-236fa ($CF_3CH_2CF_3$), and HFC-365mfc ($CH_3CF_2CH_2CF_3$) have been relatively stable. Total CO_2-equivalent emissions of the nine HFCs increased from ~60 Tg $year^{-1}$ in 2011 to ~100 Tg $year^{-1}$ in 2017. Among these nine HFCs, HFC-134a (39%) and HFC-125 (35%) make the largest contributors to the national total HFC CO_2-equivalent emissions. Cumulative contributions from China's HFC emissions to the global total HFC mole fractions and their related radiative forcing increased from 1.0% in 2005 to 10.7% in 2017. Upon comparison of global emissions with the sum of emissions from China and developed countries, an increasing difference is observed over recent years, which points to substantial additional HFC emissions from other developing countries under the Kyoto Protocol.



Update HFC-410A emission from room air conditioning sector with country-specific emission factor (bottom-up study)







Lower HFC-32 emission by updated bottom-up studies, which explain partly of the differences between our top-down estimate and previous bottom-up studies

Table 1
Parameters in the emission estimation of HFC-410A from RAC.

Stages	Production	Installing		Operation	Servicing		End-of-life	
	F kg/unit	EF_{pro}	EF_{ins}	EF_{ope}	R_{ser}	EF_{ser}	R_{en}	EF_{en}
This work	1.0	0.2%	0.2%	0.2%	0.03%	100%	8.54%	100%
Uncertainty	0.9–1.2	0.1%–0.3%	0.2%–0.4%	0.1%–0.3%	0.02%–0.04%	–	5%–12%	–
Previous study[a]	0.96	0.6%	–	2.5%	–	100%	0.7%–5.4%	75%

[a] Data source: W

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Historical and projected HFC-410A emission from room air conditioning sector in China

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[a] Meteorological Observation Center of China Meteorological Administration, Beijing, 100081, China
[b] China Household Electrical Appliances Association, Beijing, 100010, China
[c] State Key Joint Laboratory for Environment Simulation and Pollution Control, College of Environmental Sciences and Engineering, Peking University, Beijing, 100871, China

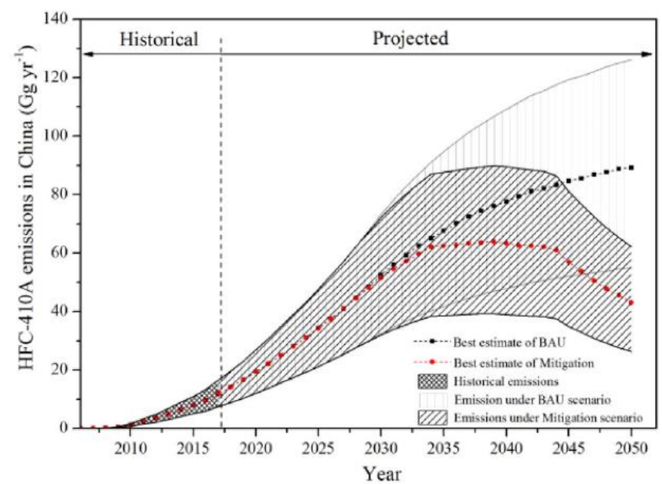
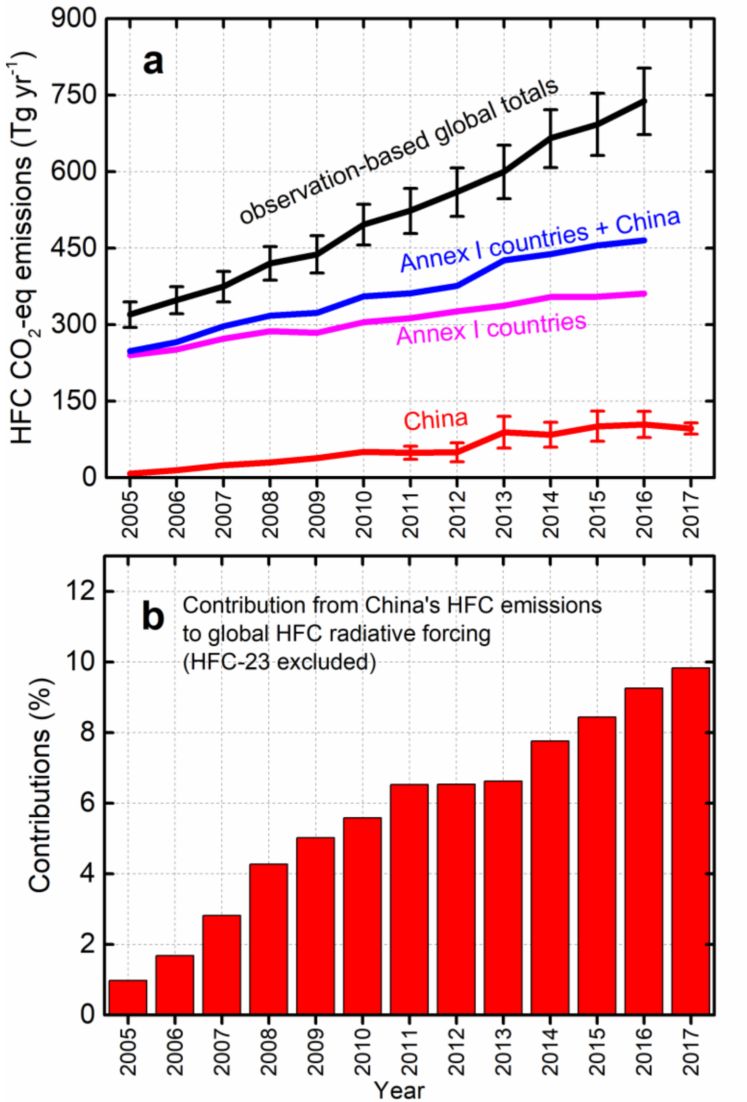


Fig. 4. Historical and projected HFC-410A emissions from RAC sector with 95% confidence intervals under the BAU scenario and mitigation scenario.

Substantial increases in HFC emissions in developing countries other than China

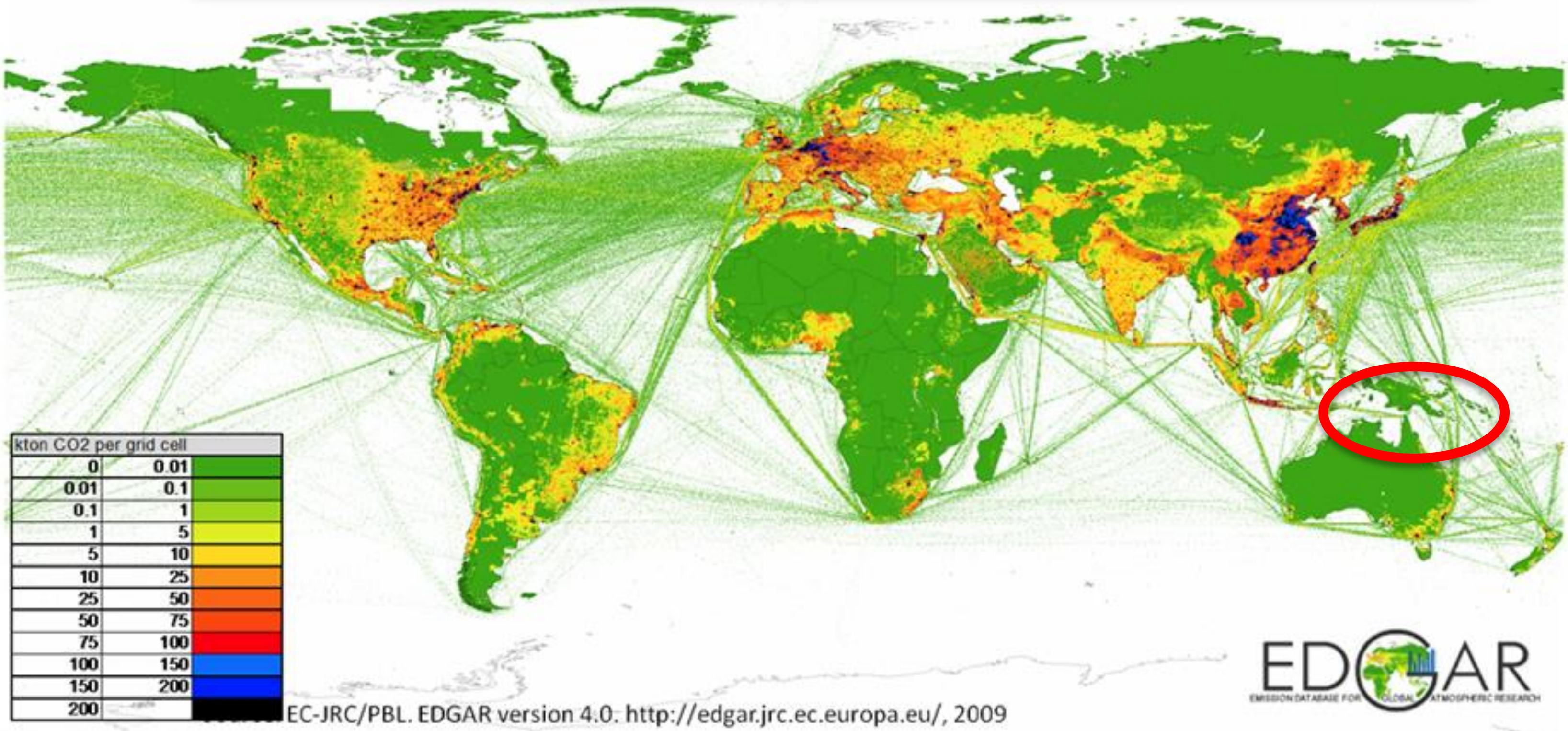


For 2005−2016, emission gap (~ 270 Tg CO_2-eq in 2016) between the summed emissions from Annex I countries and China and the global total HFC CO_2-eq emissions increased over 2005−2016, which suggests substantial increases in HFC use and emissions in developing countries (not obligated to report emissions to the UNFCCC) other than China.

Outlines

- ✓ Long term GHG observation by CMA
- ✓ F-gas emission estimate by inverse modeling
- ✓ High precision CO_2 measurement at Beijing-Tianjin-Hebei city cluster

Focused on the area with the highest CO_2 emission intensity in the world



An national Key R&D project "High Spatial-temporal Resolution Carbon Emissions Monitoring and Application Demonstration in Beijing-Tianjin-Hebei (JJJ) City Cluster" was funded for 2017-2021 with total budget $ 4.65 million

Research Objects

- **Establishment of comprehensive CO_2 observation system**

Continuous observation: 5 carbon satellites (Tansat, FY-3D, GF-5, OCO-2, GOSAT), 6 high precision CO2 monitoring station, and the high density network of 200 low-cost sensor stations

Regular intensive observation, in summer and winter of 2018/2019/2010: mobile and airborne measurement, air-core sampling, laser radar scanning

- **High resolution data assimilation system**

Simulation of atmospheric CO2 at high resolution (km, hourly), **with VEGAS model** as the core of the simulation; to quantify the uncertainty by using **two advanced data assimilation method (LETKF-Carbon\ POD-4DVar-CMAQ)**

- **Dynamic grid carbon emission inventory and its visualization in JJJ.**

Advanced inventory of JJJ city cluster at high resolution; establish multi-level (km grid, City, County, Province) carbon accounting database by bottom-up method.

Provide comprehensive information for low-carbon policy makers.

Key scientific issues

- ✓ **Develop a method to quantify carbon emission of Chinese cities**
- ✓ **Monitoring CO_2 emission at factory-level**
- ✓ **Evaluate the recent low carbon policies**

1 Scattered coal consumption banned

2 Clean air target leading to 50% reduction of steel production in 2017

3 Replacing coal with nature gas policy

etc

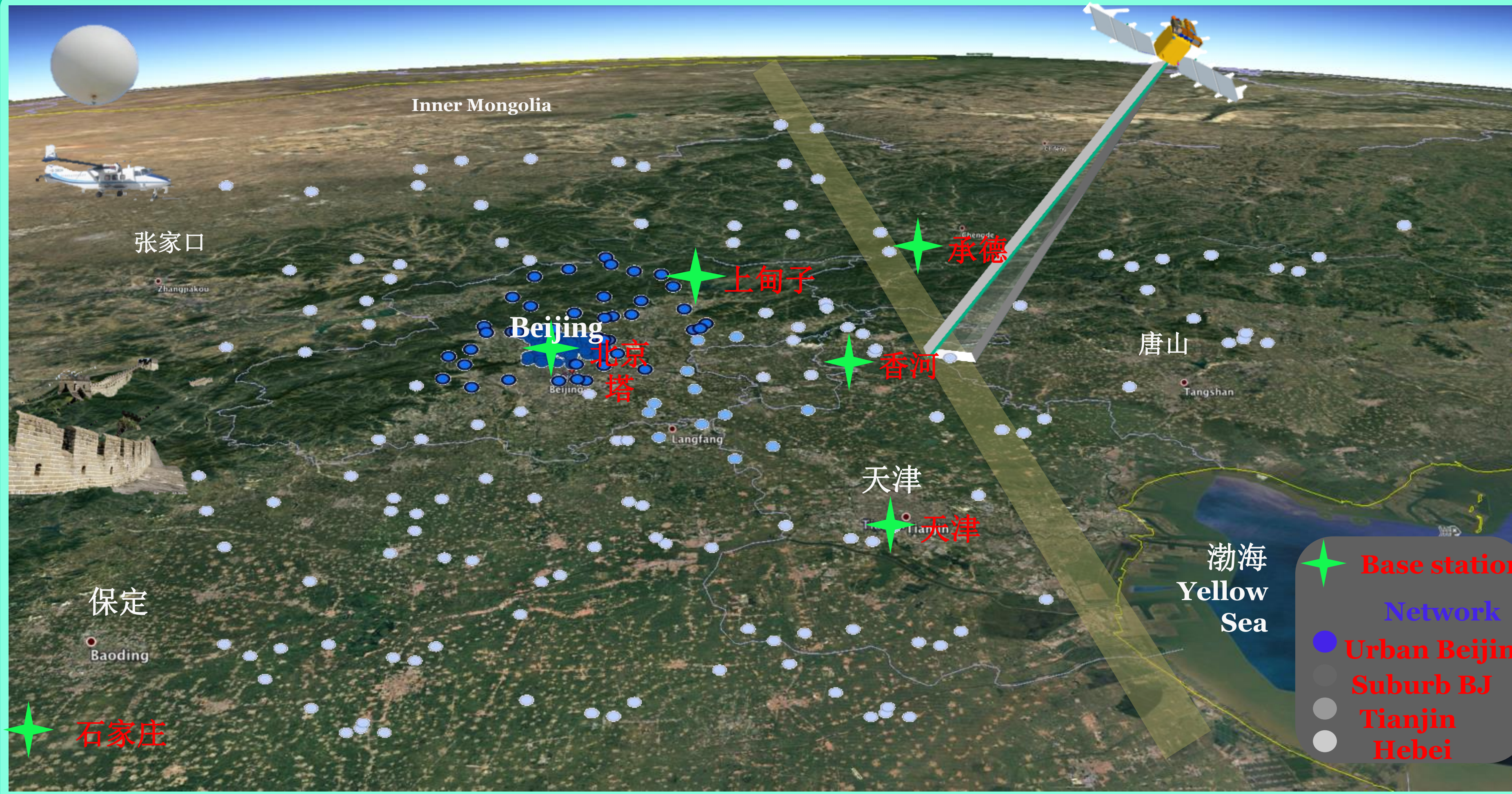
A carbon monitoring network of this project

Intensive observation: airplane, LIDAR, air core, mobile, and balloon

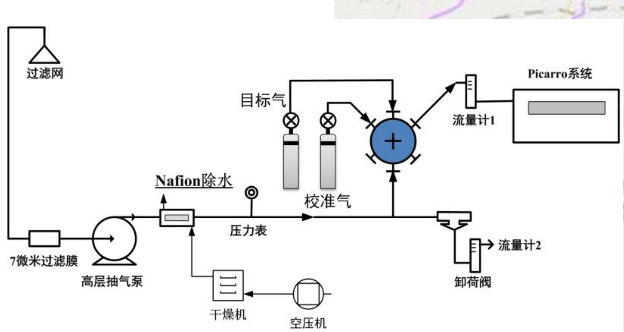
High precision backbone observation station

High-density observation network

Chinese and international carbon satellite



Ground base high precision observation network



Auto calibration system

- ✓Instrument： Picarro 1301/2301/2401
- ✓Frequency： In-situ, 1 min
- ✓Calibration: every 4 hours, traced to WMO scale
- ✓Observation period： 2018-07-01 to 2020-06-31, hope to extend

September 2018

January to February 2019

July 2019

Picarro Car

Picarro/Tower

Tall towner

0-350m

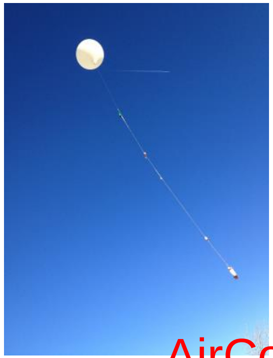
Laser radar

0-1km

Picarro 1301m

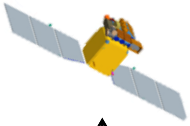
Airplane

0.6-6km



AirCore

0-30km

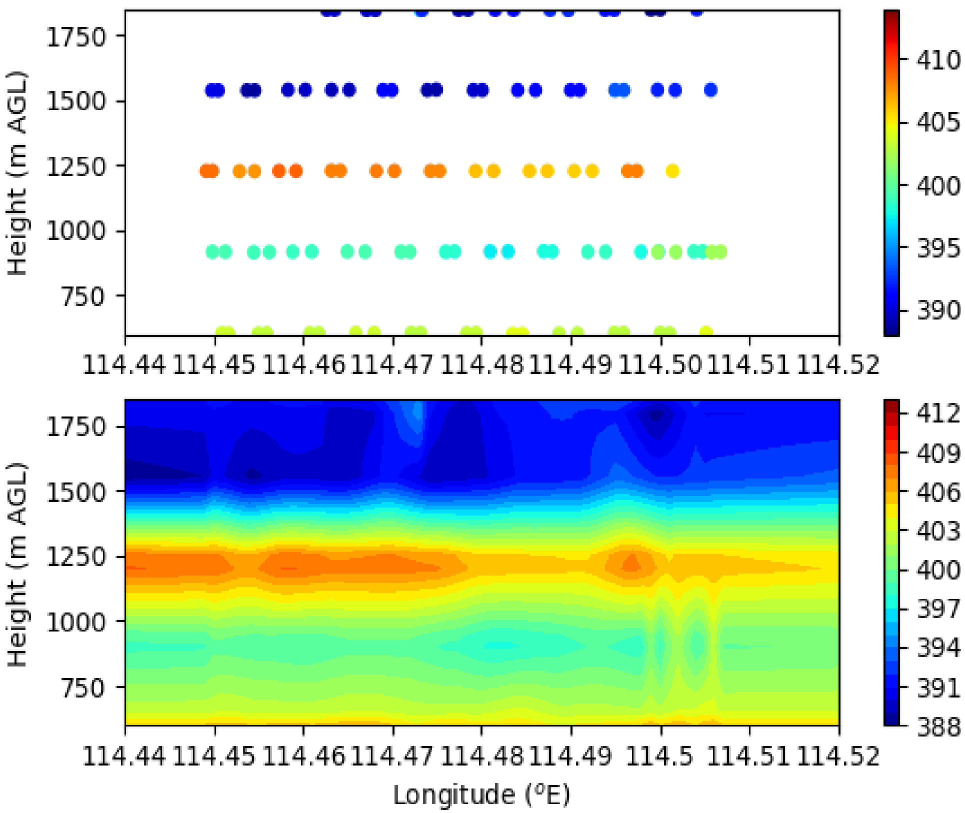


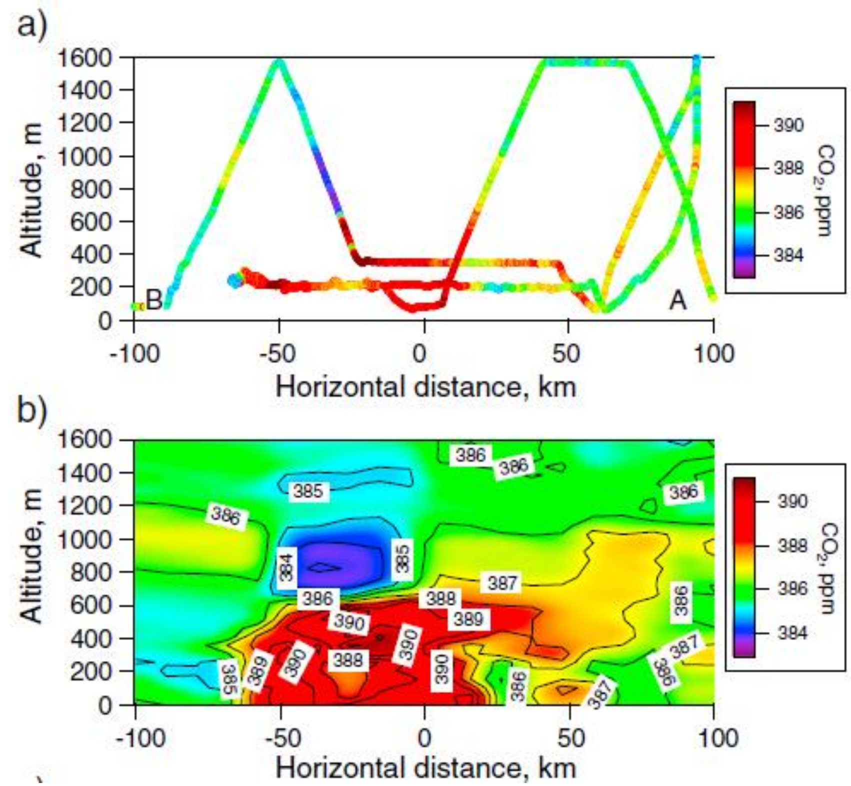
TANSAT/GOSAT

Population: ~10 million (5 million urban)
GWP: 587 billion CNY
Industry output: 291 billion CNY

CO_2 emission (bottom-up): 133 billion ton (2015)

CO_2 vertical profile





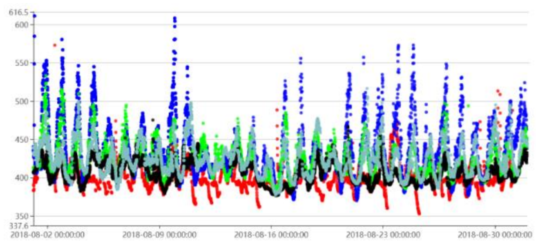
(S. J. O'Shea, et al., 2014)

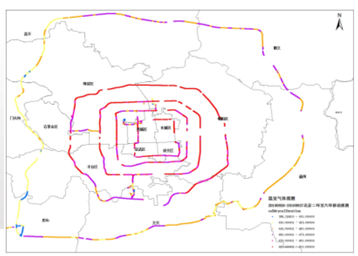
This study in Shijiazhuang

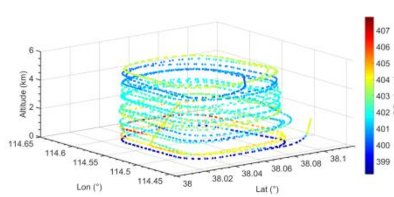
CO_2 net sink during daytime at Shijiazhuang on September-10-2019

Ongoing work :

- ✓ **Quantify CO_2 emission by inverse modeling or mass balance method**
- ✓ **Comparison with inventory**







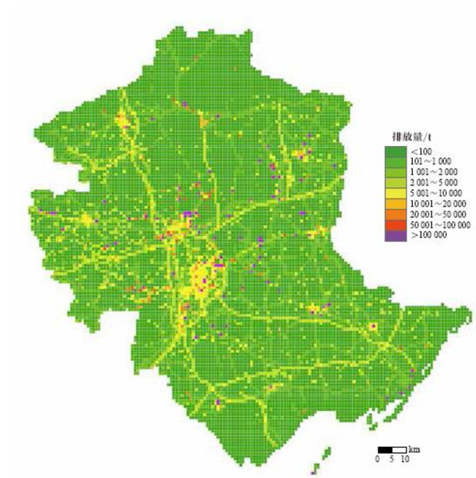


图 6-3 唐山二氧化碳直接排放 1 km 网格
Figure 6-3 1 km resolution grid map of Tangshan direct CO_2 emissions

Summary

- ✓**CMA has conducted long term high precision GHG measurement at background stations in China since 1990s.**
- ✓**F-gas emissions were estimated by inverse modeling from 2011 to 2017.**
- ✓**Megacity CO_2 project of Beijing-Tianjin-Hebei city cluster was funded to quantify carbon emission by top-down method at fine resolution.**

Thank you!

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