Monitoring Global Carbon Dioxide from space: the TanSat mission and carbon flux investigation study in China

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Content

1. TanSat algorithm development-XCO_2 and SIF
2. Validation technique and field campaign
3. Flux inversion and application
4. Future plan

TanSat mission

- National High Technology Research & Development Programs by Ministry of Science and Technology of China (MOST) (2011-2017)
- Strategic Priority Research Program from Chinese Academy of Sciences
  - ➢ Climate Change: Carbon Budget and Relevant Issue
  - ➢ Space Science: Scientific Research Satellite
- NSMC (CMA) -- (2016- NOW) , Ground segment—Satellite data receive and process

TanSat mission kicked-off at 2011, launched at 2016

TanSat mission will join the ESA 3rd Party mission

Term-1

Measurement Goals

XCO2

1~4 ppmv

Monthly

500 x 500 km²

Term-2

Measurement Goals

CO2 Flux

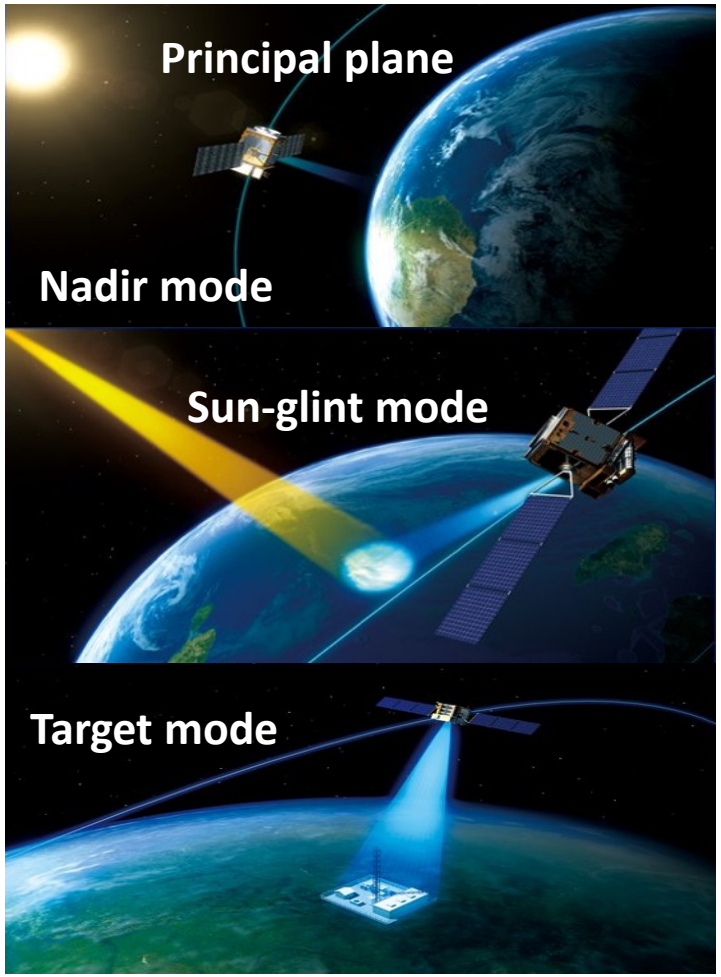
Relative flux error

20%

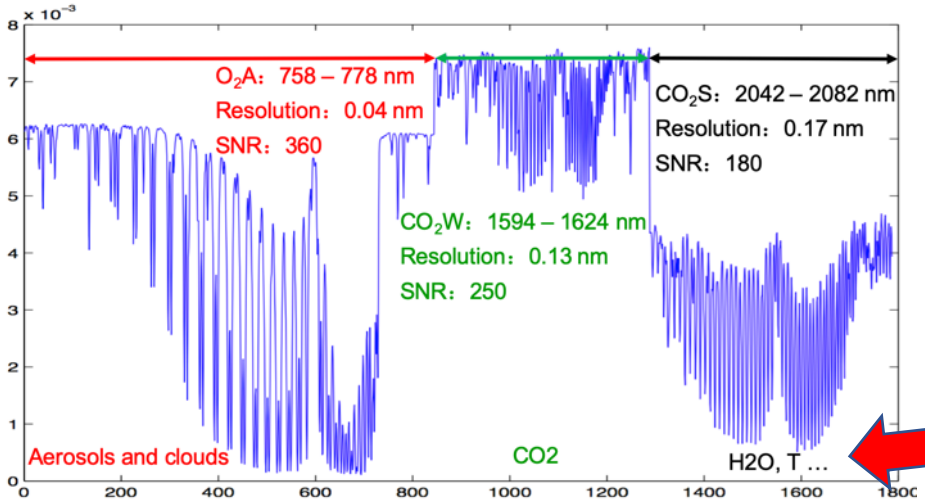
Monthly

500 x 500 km²

TanSat & Instrument

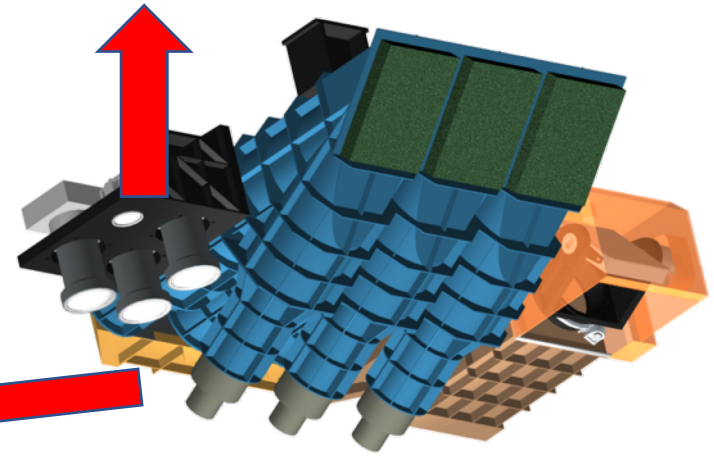


Name	Characters
Orbit type	sun-synchronous
Altitude	700 km
Inclination	98°
Local time	13:30
Weight	500Kg



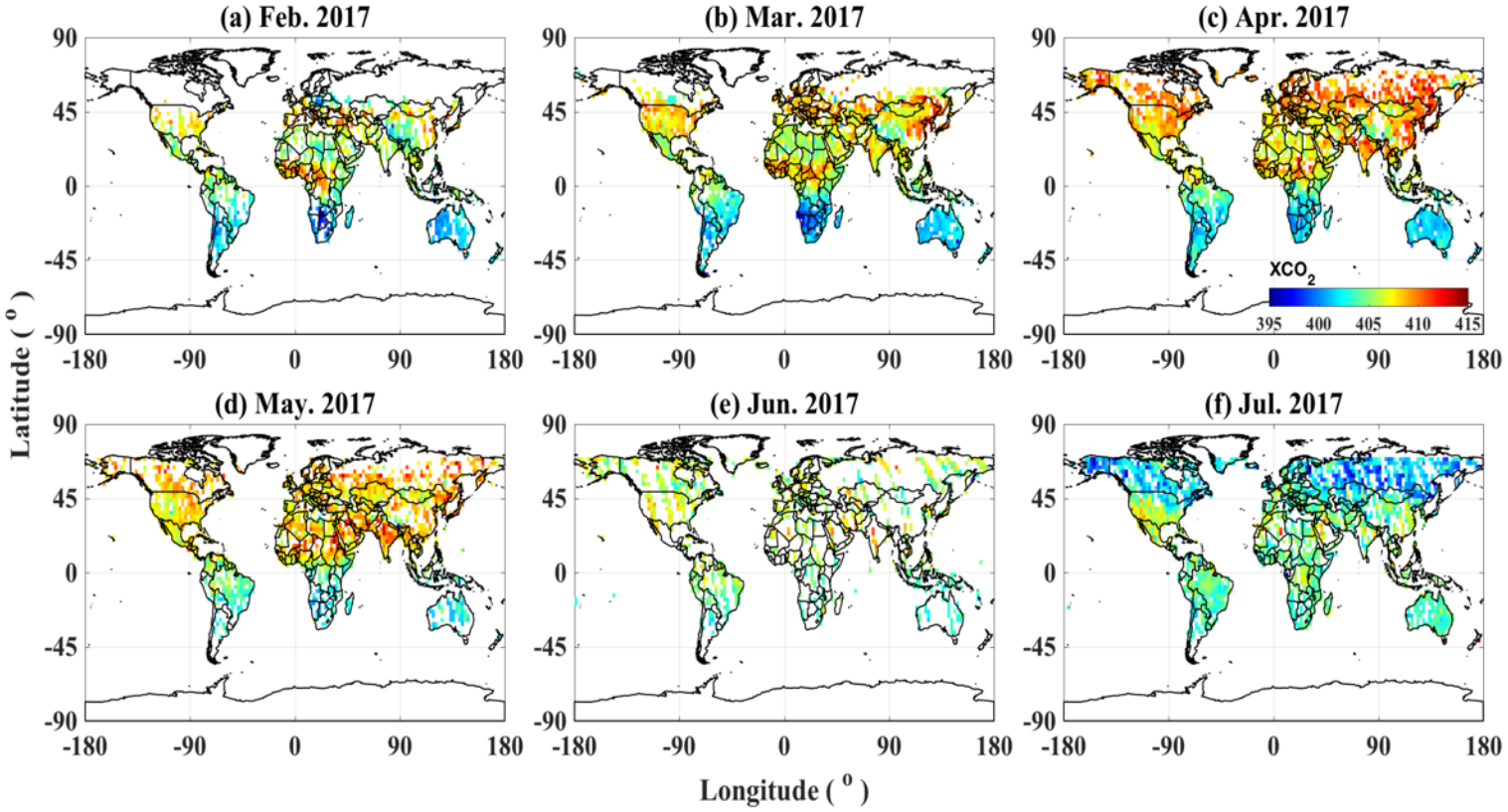
Cloud and Aerosol Polarization Imager - CAPI

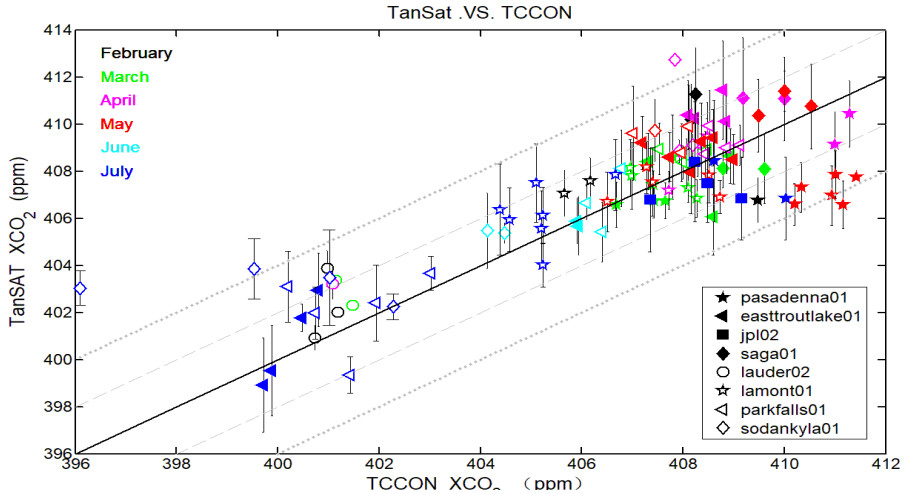
- A wide field of view moderate resolution imaging spectrometer with polarization channel
- Ultraviolet: 0.38μm
- Visible: 0.67μm
- Near infrared: 0.87, 1.375 and 1.64μm
- Polarization: 0.67 & 1.64 μm



Preliminary results from TanSat

IWGGMS-15



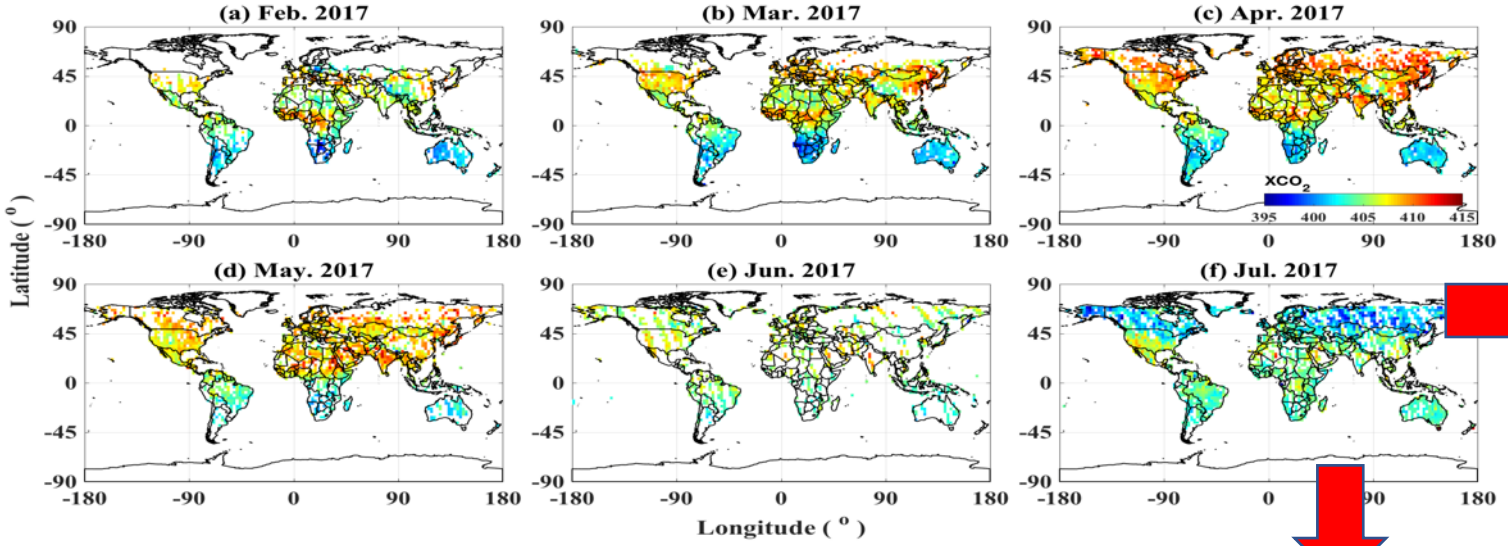


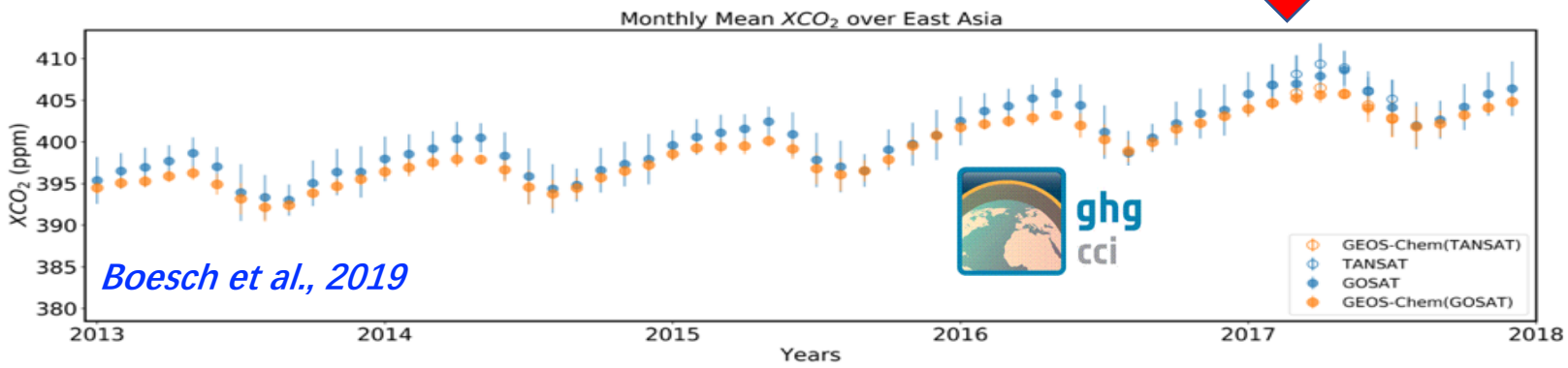
Site	Precision (ppm)					
	February	March	April	May	June	July
Pasadena, CA	2.53	13.20	1.46	3.08	--	2.27
East Trout Lake, Canada	--	0.49	2.12	0.75	0.67	1.01
Saga, Japan	4.22	1.22	1.56	0.96	--	--
Lauder, New Zealand	--	--	2.12	--	--	--
Lamont, OK, USA	0.60	1.31	0.81	0.97	--	1.49
Park Falls, WI, USA	--	0.80	0.72	0.85	1.88	1.72
Sodankyla, Finland	--	3.05	2.92	2.29	2.76	4.02
JPL	--	--	--	--	--	1.35
Average	2.45	3.35	1.67	1.48	1.77	1.98

TanSat version preliminary data product
Retrieved from V1.0 L1B data by IAPCAS

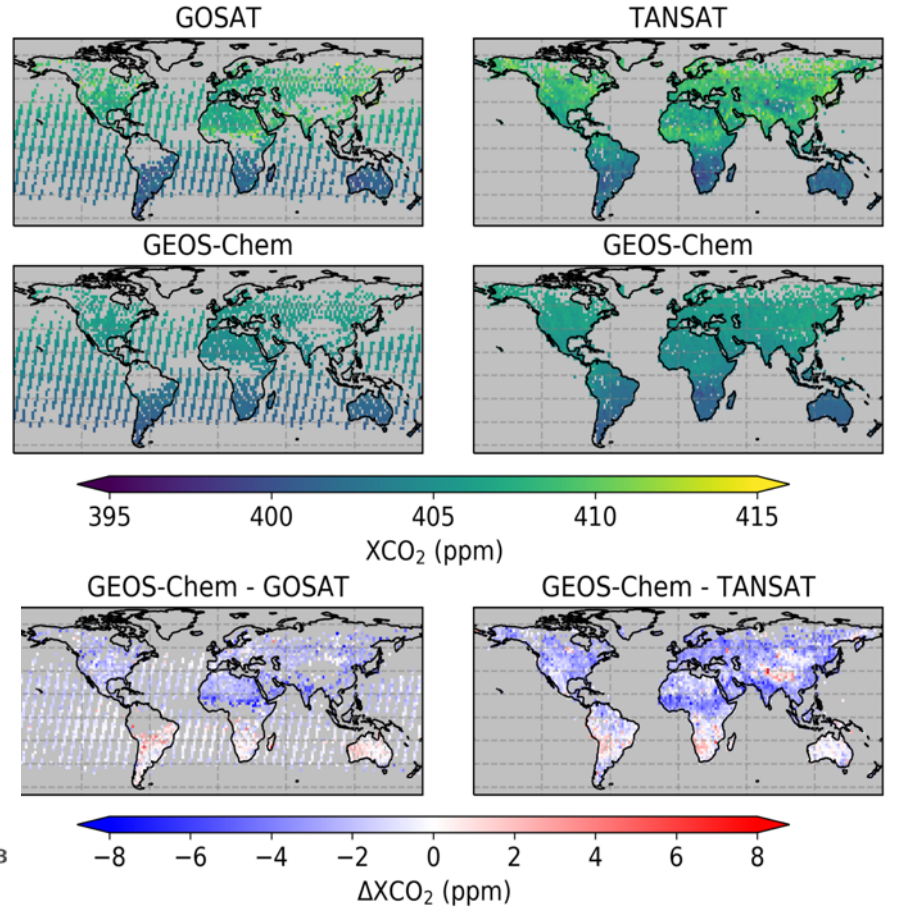
Liu et al., 2018

Model comparisons





GEOS-Chem model data from University of Edinburgh



Acknowledgement: ESA-MOST Dragon programme

Improve

IWGGMS-15

Yang et al., 2019

We involved innovation methods on TanSat measurement correction to improve the fitting residual and retrieval accurate and precision.

TanSat XCO2 retrieval, Inter-comparison and validation

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On 22 Dec. 2016, China launched a carbon dioxide observation satellite, TanSat, which is the first Chinese greenhouse gas monitoring satellite that has been supported by the Ministry of Science and Technology of China, the Chinese Academy of Sciences, and the China Meteorological Administration. In-orbit calibration tests were completed in the summer of 2017, and the performance of the instrument has since been evaluated in test sessions. In this study, we involved two retrieval algorithm, 1. IAPCAS, is the institute of Atmospheric Physics Carbon dioxide retrieval Algorithm for Satellite remote sensing, which has also been used for GOSAT (ATANGO) and OCO-2 retrieval studies, 2. UoL-FP, University of Leicester Full Physics algorithm that has been used for GOSAT retrieval and provide XCO2 product to the ESA Climate Change Initiative (CCI) and the Copernicus Climate Change Service (C3S). The retrieval accuracy and precision of both, the IAPCAS and UoL-FP has been well investigated by verifying them against TCCON measurement during previously studies. In this poster, we introduce our new results on improving the TanSat retrievals and shows the results of inter-comparisons between two algorithm and validation against TCCON measurements.

University of Leicester retrieval algorithm

IAPCAS retrieval algorithm developed for TanSat retrieval

In this study, we have involved many innovati… correction in order to improve the fitting residual and retrieval accurate and precision, which shows a signi… CO2 retrieval results as indicate in following figures.

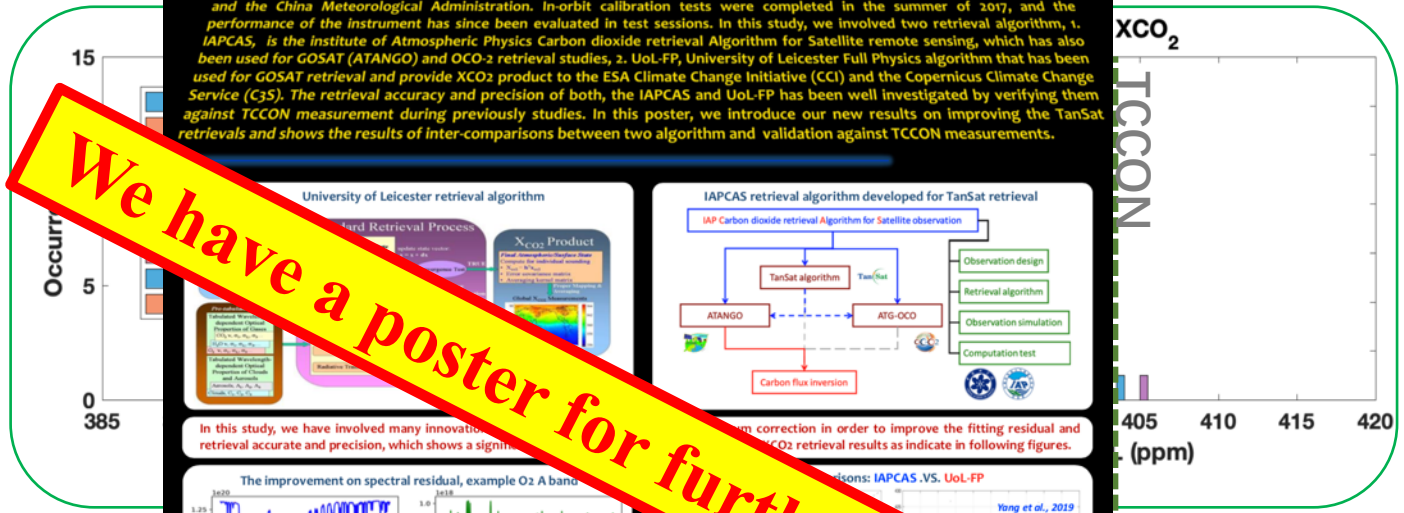
The improvement on spectral residual, example O2 A band

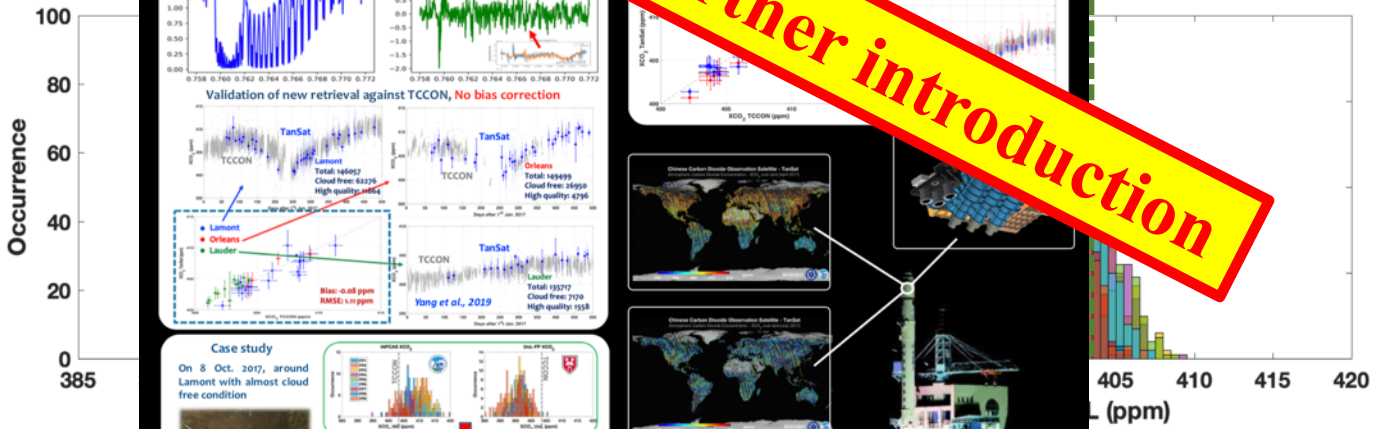
Validation of new retrieval against TCCON, No bias correction

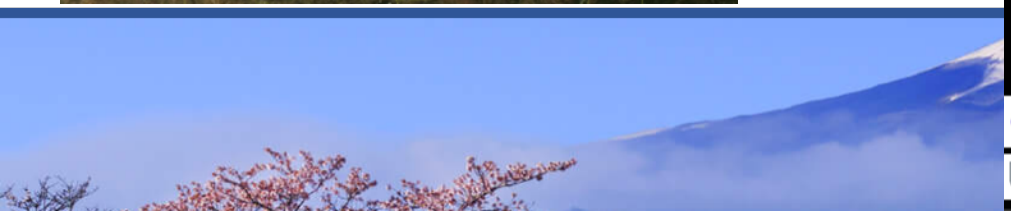
Case study

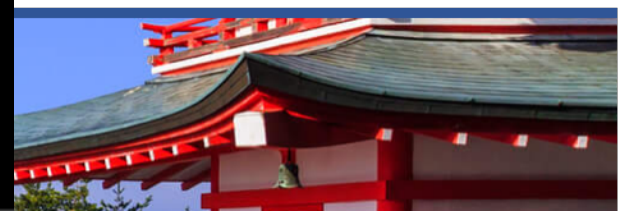
On 8 Oct. 2017, around Lamont with almost cloud free condition

We have a poster for further introduction



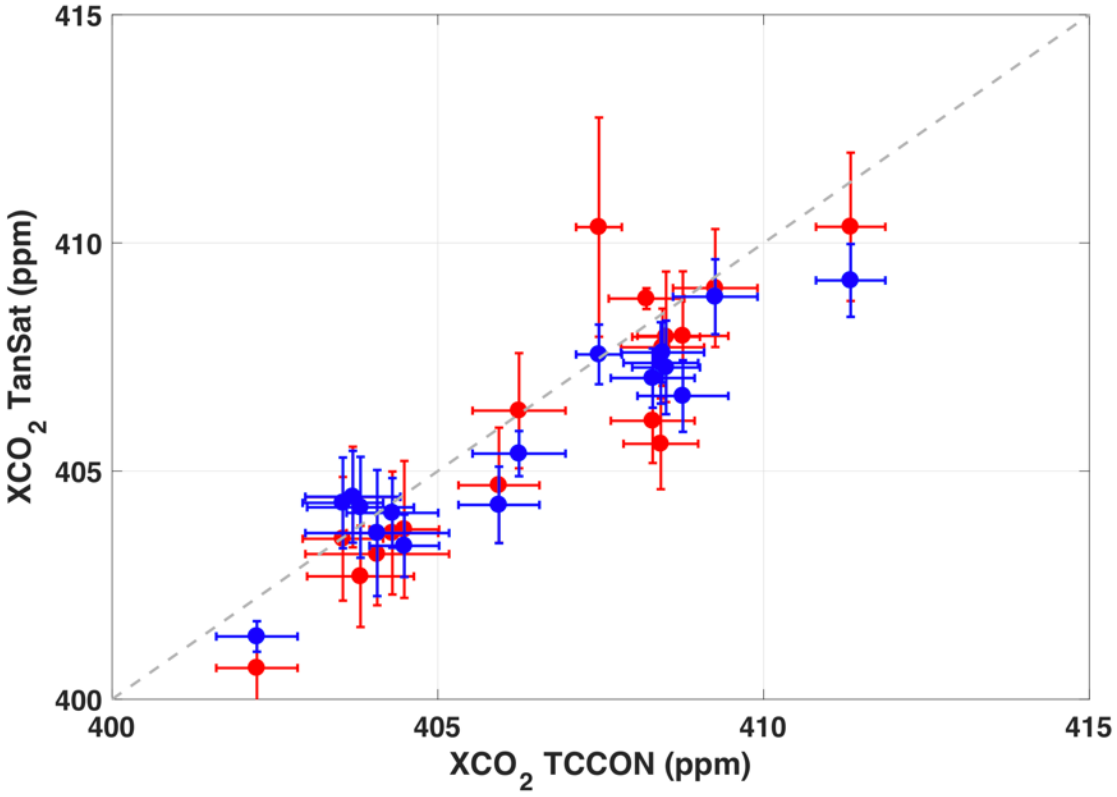


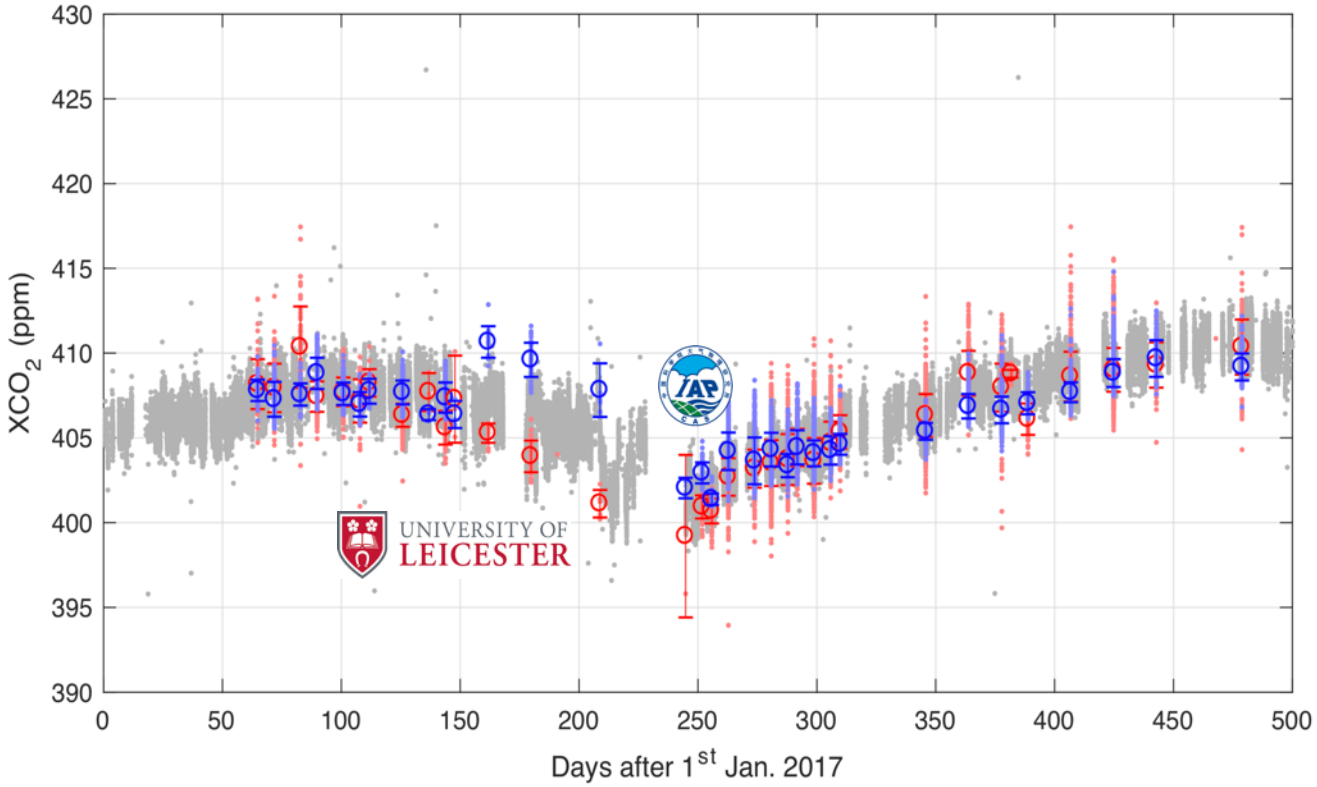




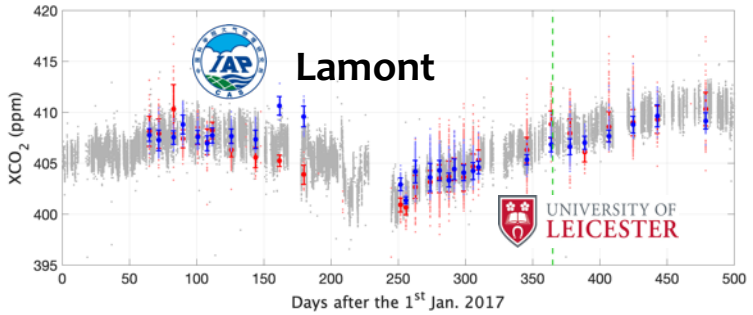
Validation and inter-comparisons

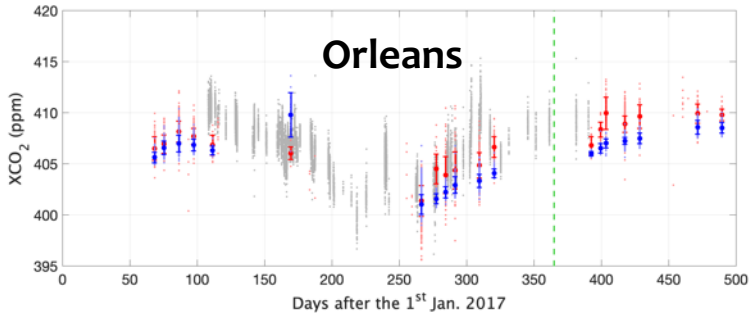
Yang et al., 2019

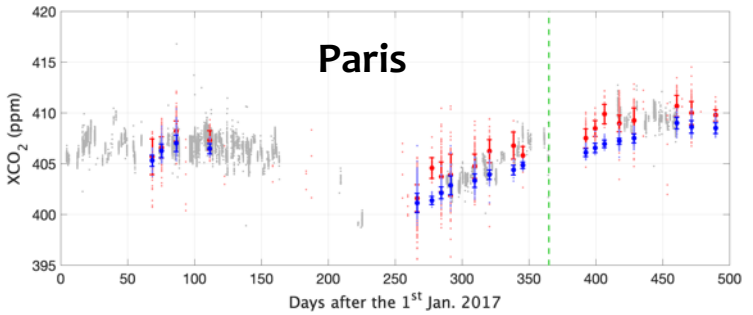


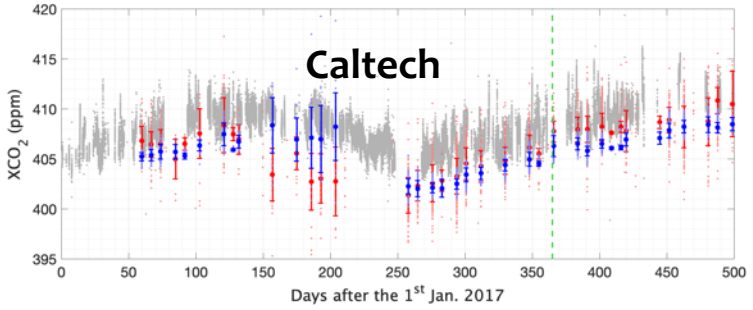


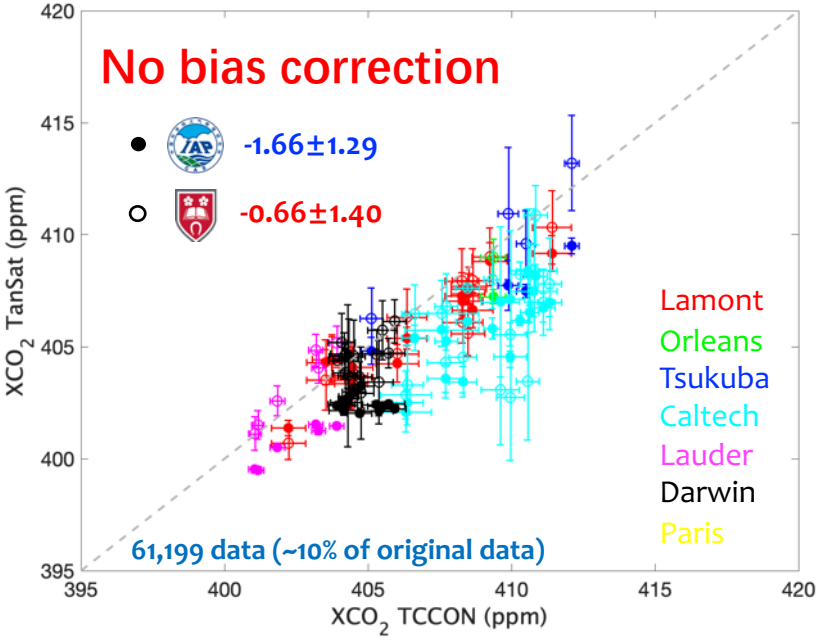
IAPCAS .VS. UoL-FP

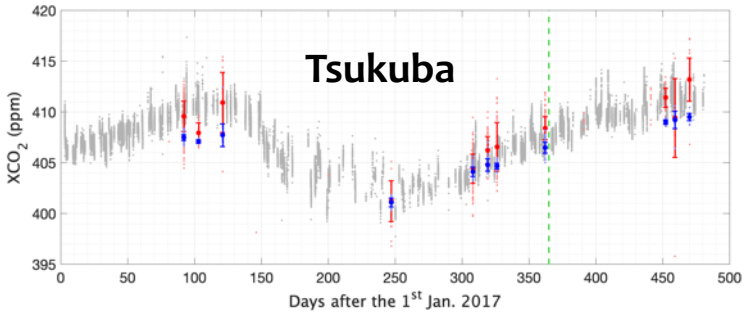


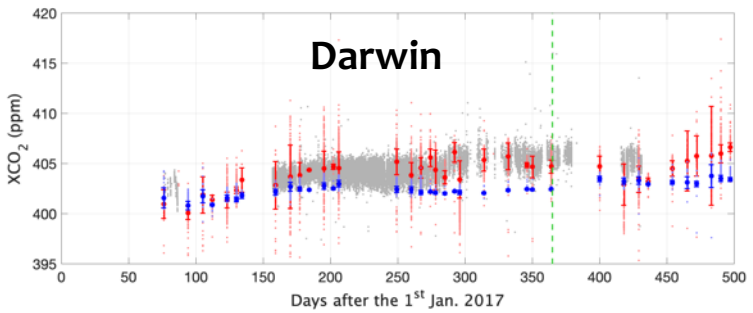


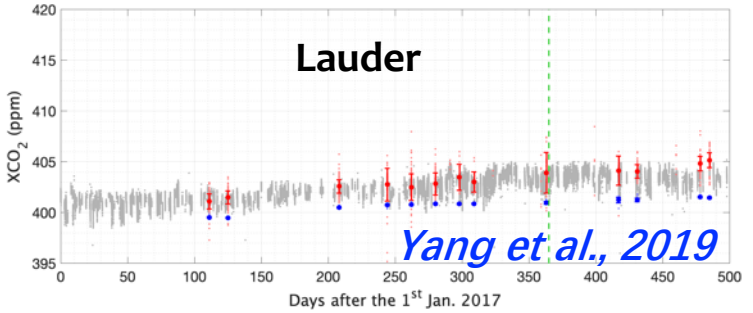










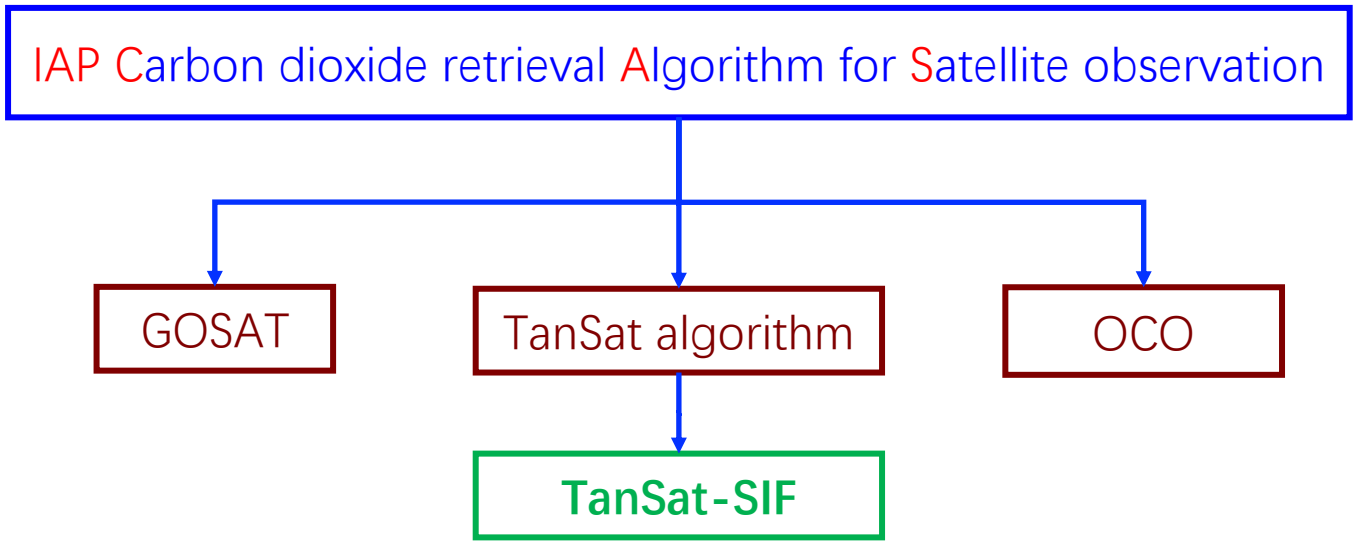


Yang et al., 2019

Preliminary validation

Sites	Bias (ppm)	Precision (ppm)	Mean RMSE (ppm)	Sampling quantity
Lamont	-0.54	1.03	0.79	11,864
	-0.84	1.33	1.17	
Caltech	-3.45	1.15	0.88	21,775
	-3.03	2.04	1.65	
Darwin	-1.84	1.59	0.27	16,757
	0.13	1.66	1.30	
Tsukuba	-2.51	1.36	0.48	915
	-0.25	1.87	1.88	
Lauder	-1.86	0.34	0.09	1,558
	0.76	0.46	1.06	
Orleans	-1.09	0.78	0.55	4,796
	0.32	0.66	1.13	
Mean	-1.66	1.29	0.52	61,199
	-0.66	1.40	1.32	

SIF retrieved from TanSat measurement



TanSat SIF product release approaching……

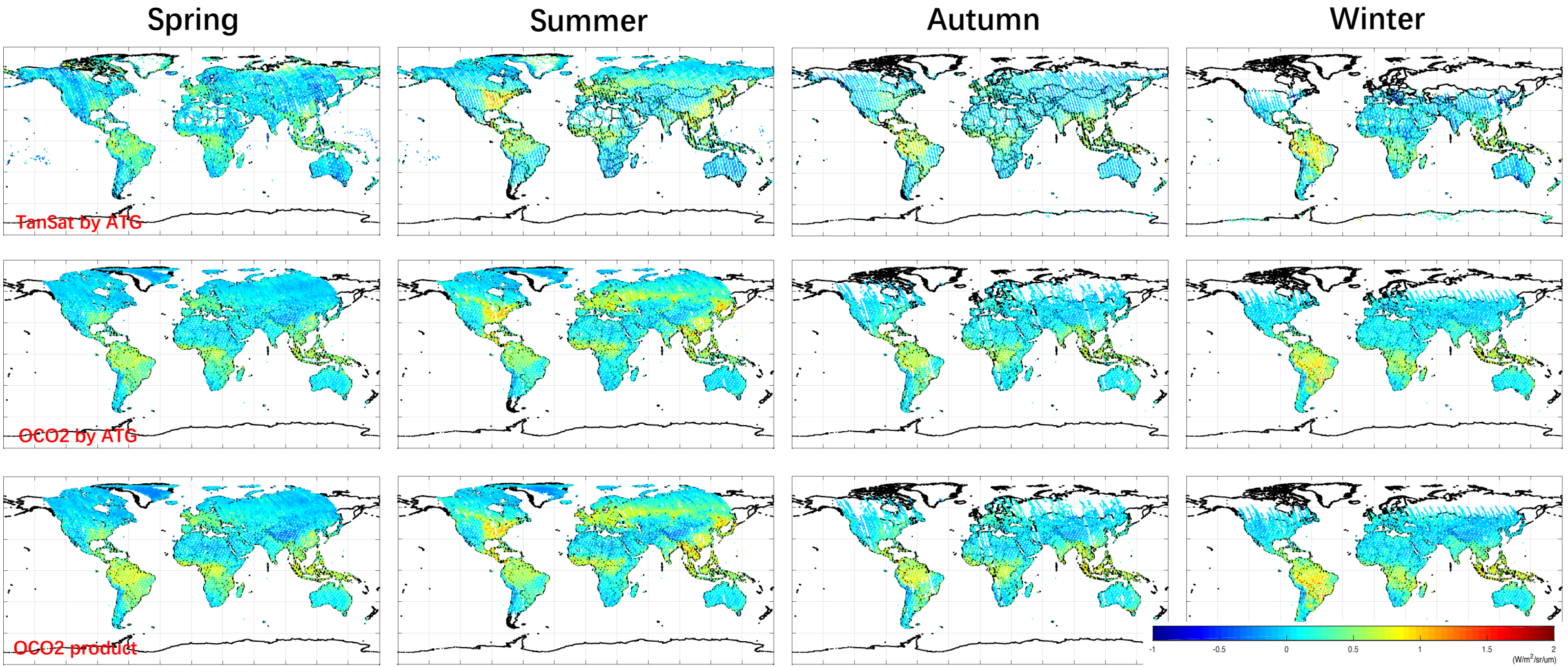
(Frankenberg et al., 2011)

Wavenumber: 12982~12988 cm-1

A low-order polynomial to approximate the scattering and surface reflection terms

State vector element	note
Relative SIF	Relative contribution of SIF to continuum
OD scale	Scale of O2 absorption
polynomial coefficient	Coefficient of the low-order polynomial
Wavenumber shift	Wavenumber shift caused by instrument movement

Inter-comparison and seasonal variation of SIF



- ATG-SIF is developed to retrieve SIF from space measurement of high resolution spectrum in O2-A
- Inter-comparison between TanSat and OCO-2 retrieval data and official product is performed to test ATG-SIF
- SIF seasonal variation and regional character is to be discussed

(L. Yao post section 5-1)

EM27/SUN Coordinate measurements

(a)

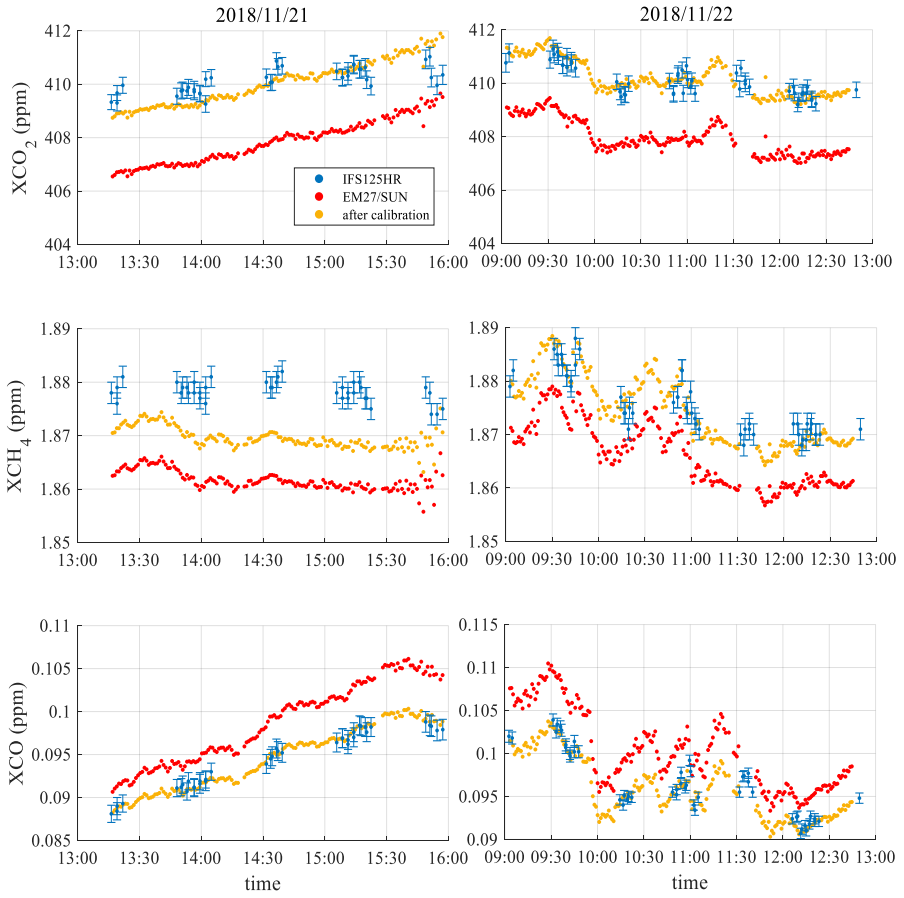
(b)

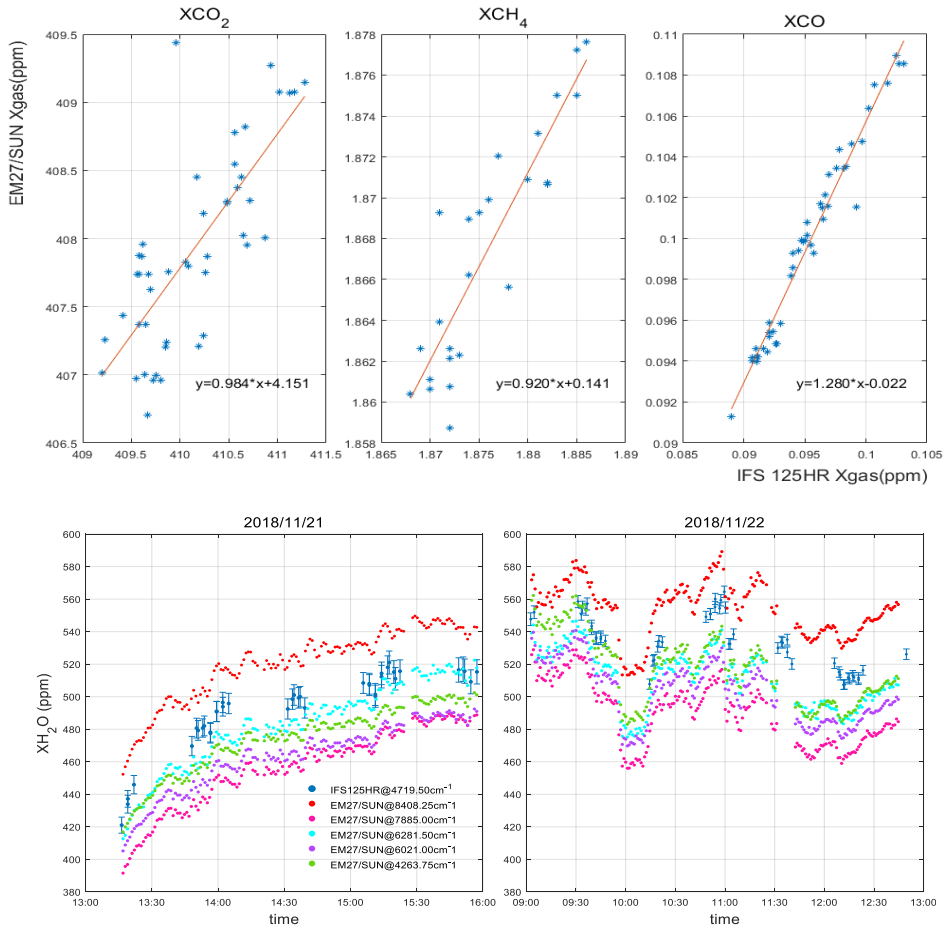
(c)

(a) Intercomparison measurements of X_{gas} measurements using EM27/SUN and IFS 125 HR in Xianghe
(b) No. 095 EM27/SUN observations on the roof terrace of IAP
(c) Intercomparsion measurements of four EM27/SUN (095,106,109,110)

(K. Che post section 6-5)

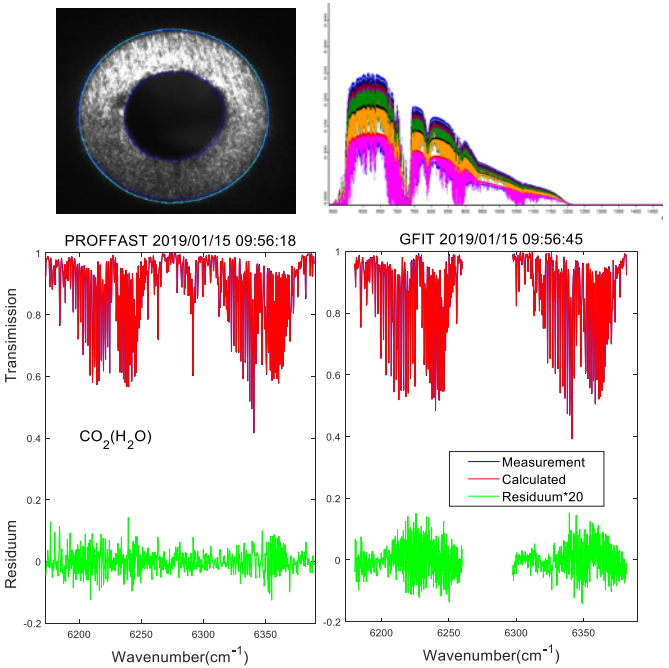
(a) Intercomparison measurements of X_{gas} measurements using EM27/SUN and IFS 125 HR in Xianghe

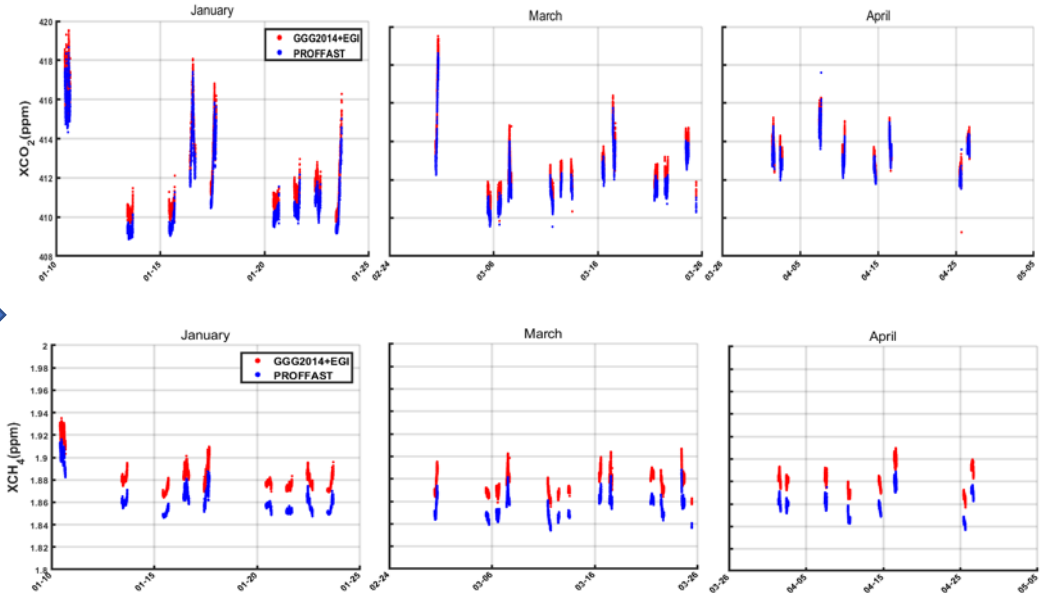


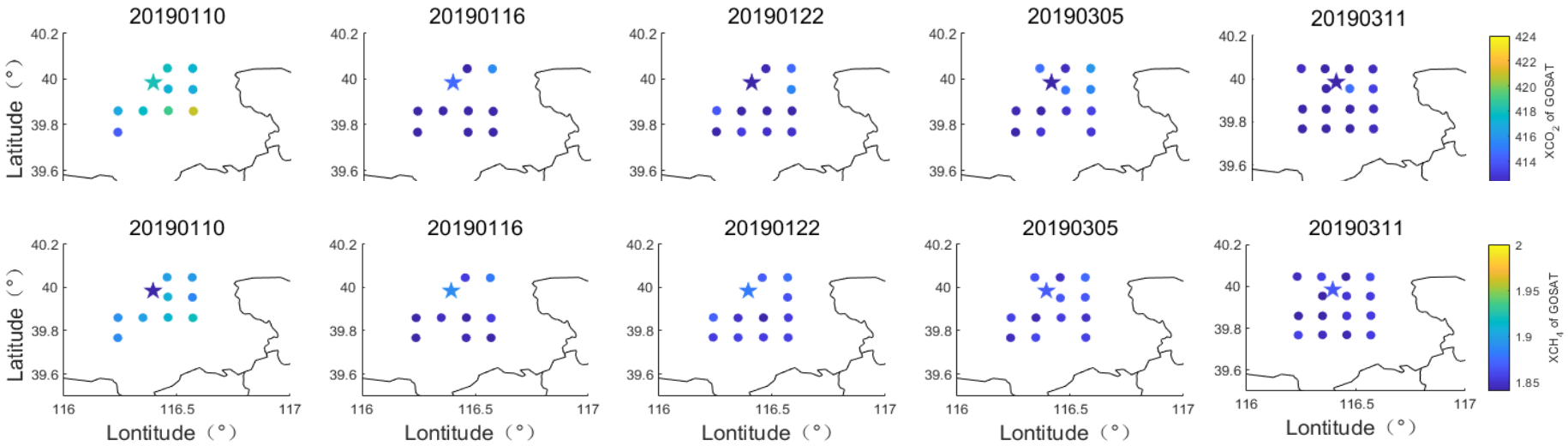


We applied PROFFAST for EM27/SUN data processing ,GGG2014 for IFS 125 HR and found an average bias of 2.1ppm, 10ppb, 4.8ppb for XCO_2, XCH_4 and XCO respectively.

(b) No.095 EM27/SUN observations on the roof of IAP







Algorithm comparison

(GGG2014+EGI & PROFFAST)

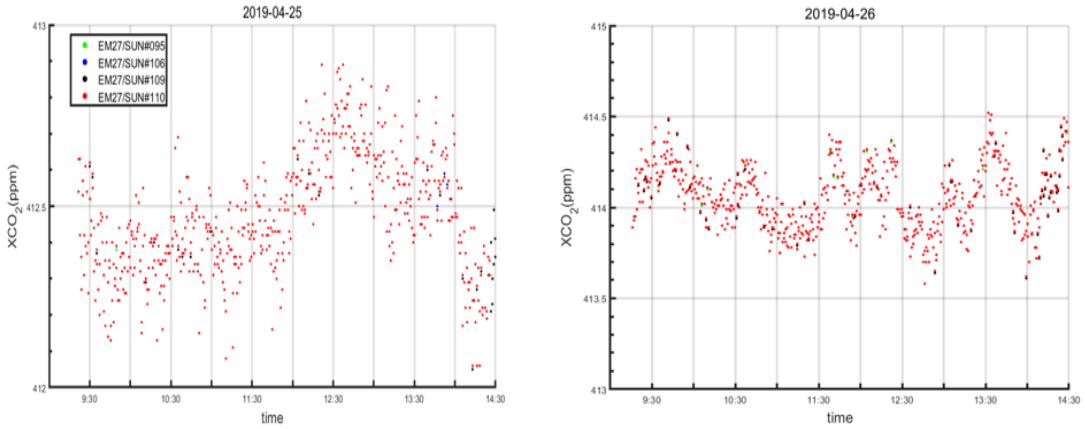
- Correlation coefficient：
  XCO_2 ~ 0.9911
  XCH_4 ~ 0.9922
- Systematic differences：
  XCO_2 ~ 0.85±0.34 ppm
  XCH_4 ~ 20.7±2ppb

GOSAT data comparison

- Bias:
  XCO_2 ~ 0.07ppm
  XCH_4 ~ 50ppb.

(c) Intercomparsion measurements of 4 EM27/SUN

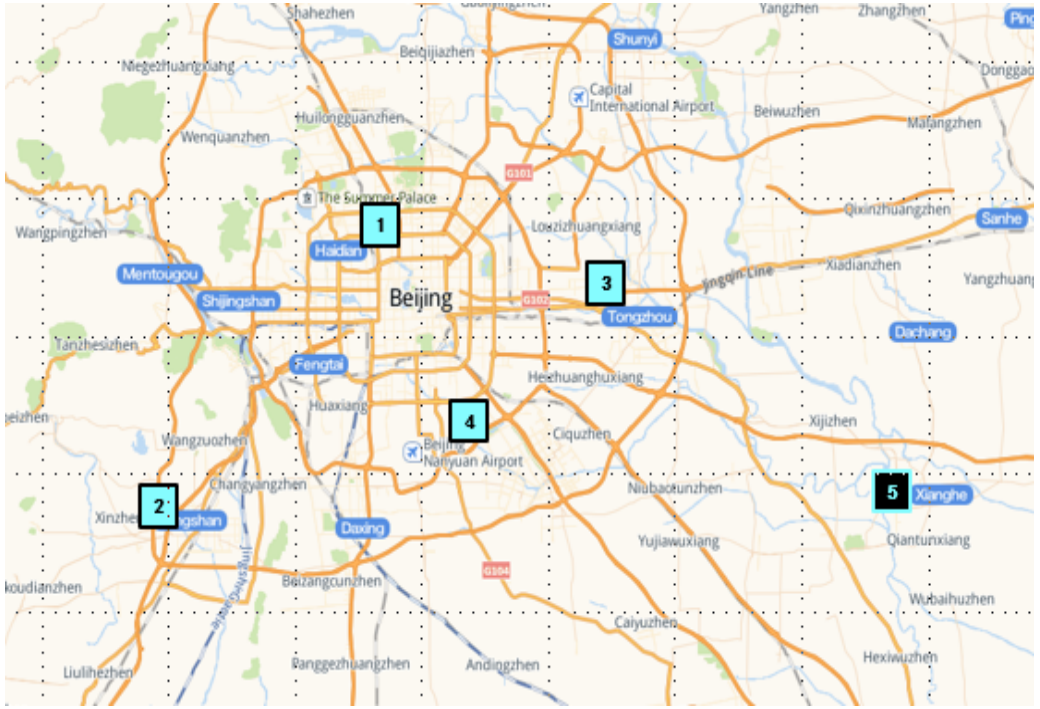
Retrieved XCO2 values based on 4 EM27/SUN (095,106,109,110)



Result of different EM27/SUN measurements at the same time and location is identical.

We will deploy our four EM27/SUN around Beijing

Map showing the measurement stations around Beijing (blue block indicates EM27/SUN measuremet, black block indicates IFS 125 HR measurement)



Aircore campaign 2018 in Inner Mongoria

13th – 14th June

Xilin Hot
(116E, 43.9N, 1004m)

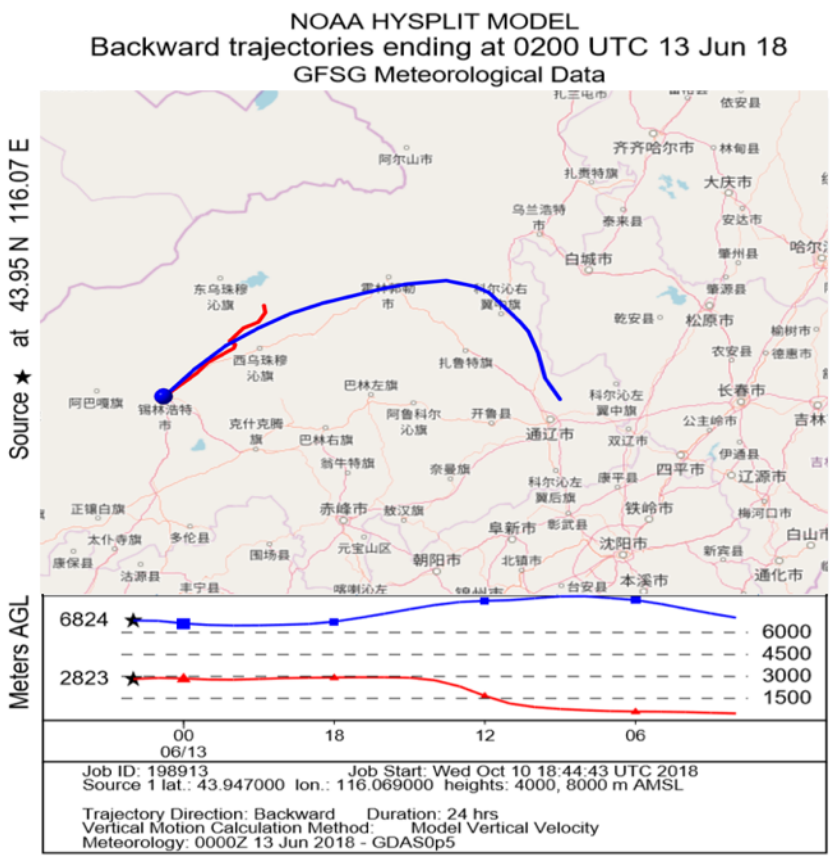
12th – 13th November

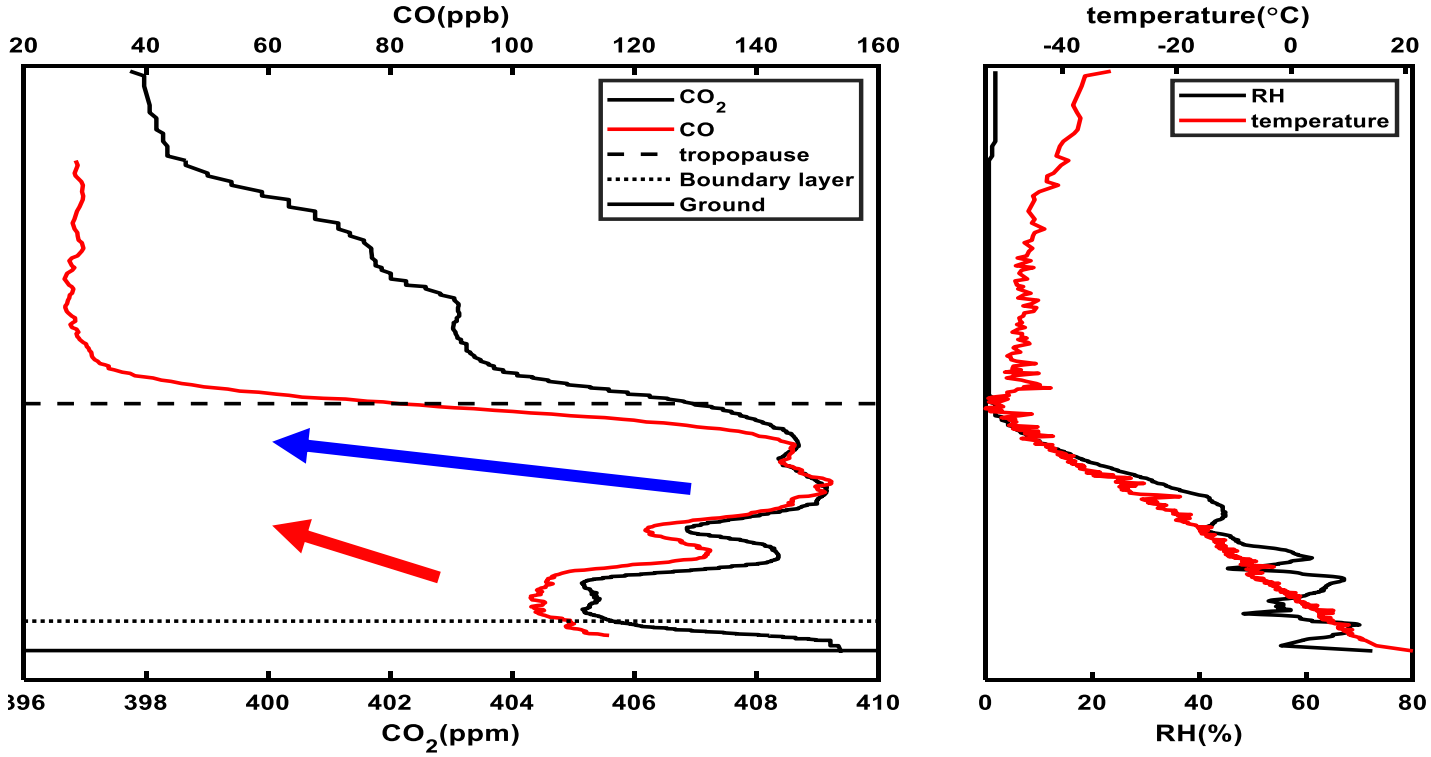
Urad Middle Banner
(108.5E, 41.59N, 1300m)

(Y. Yi post section 6-3)

Profiles

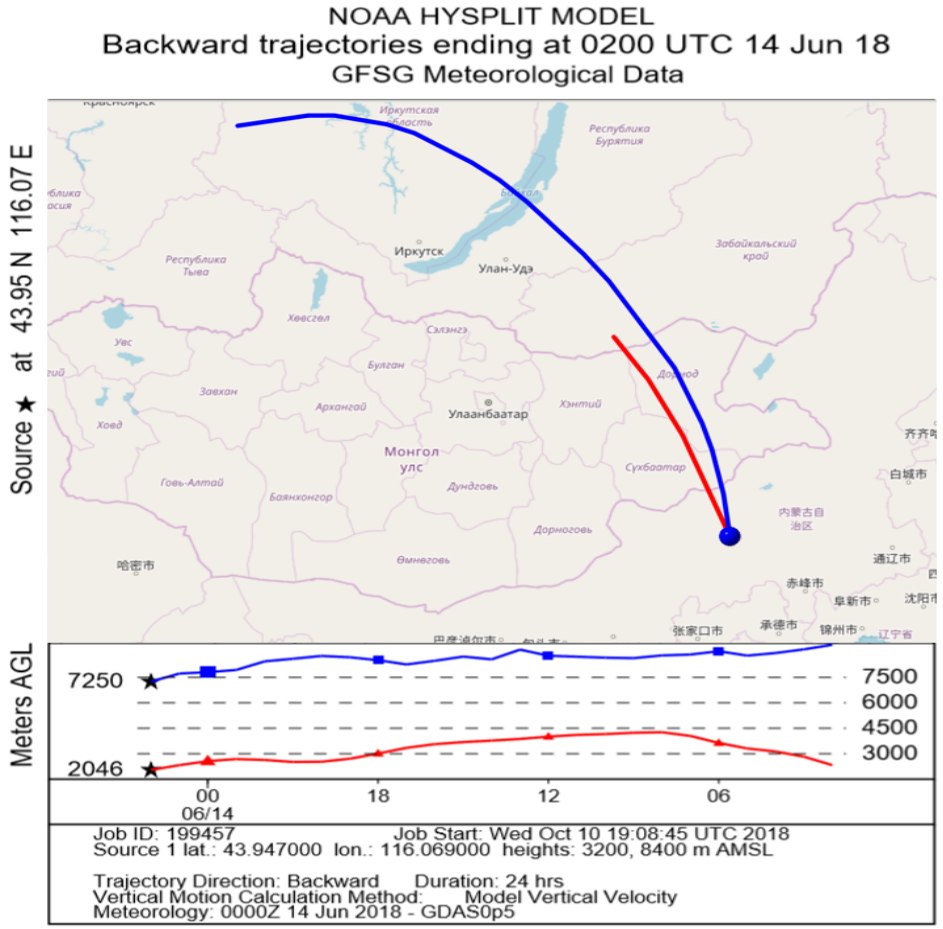
13th June

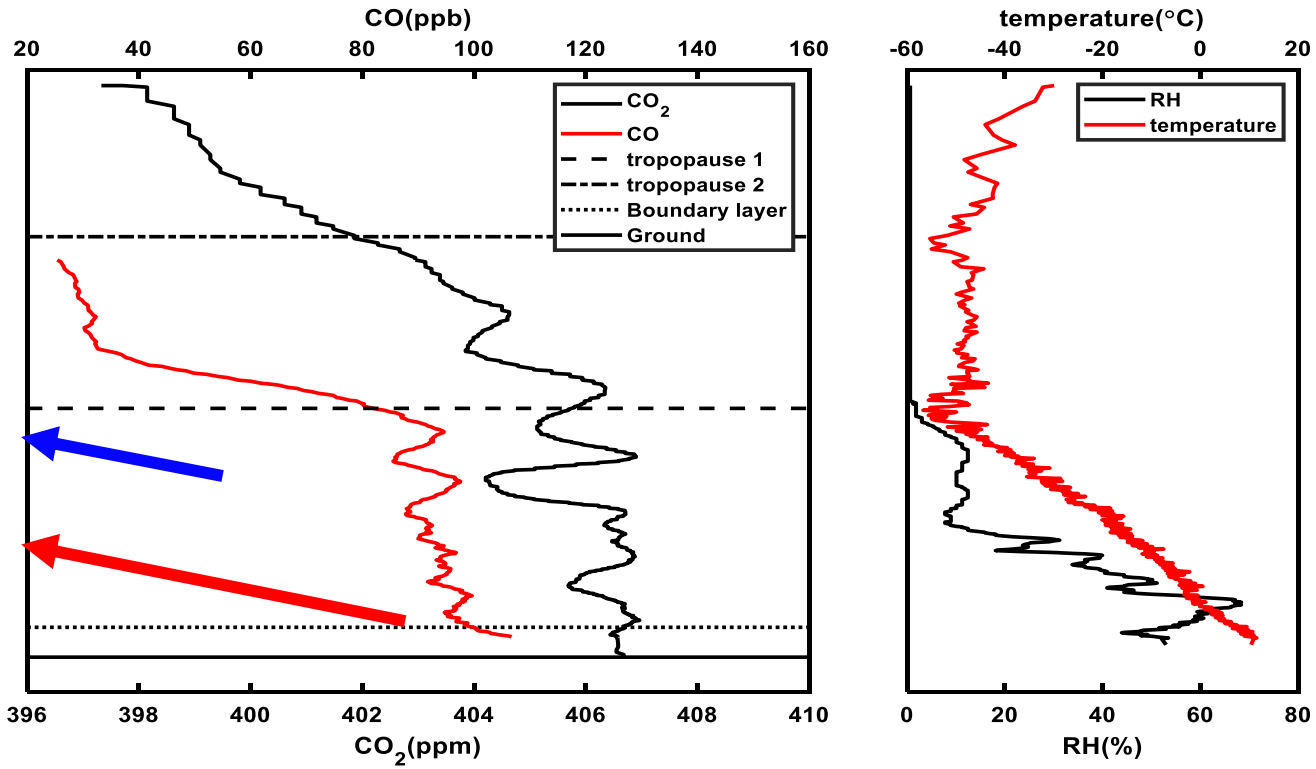




Profiles

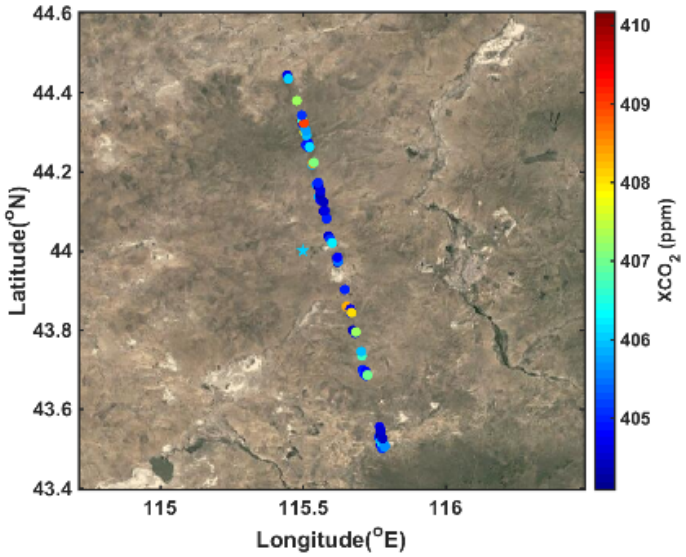
14th June



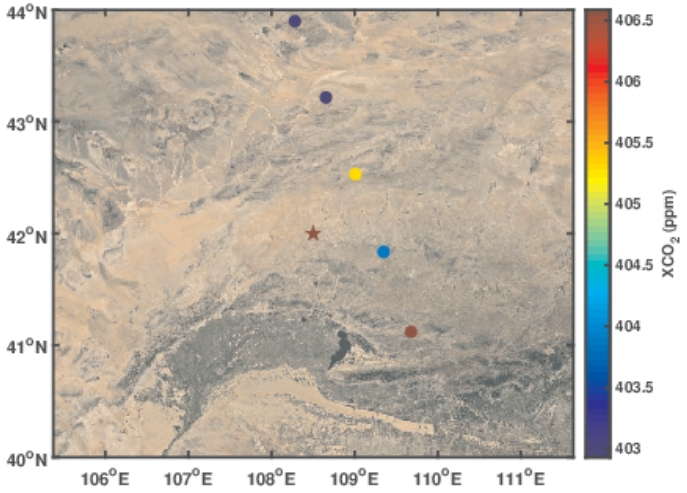


(Z. C ai post section 3-2)

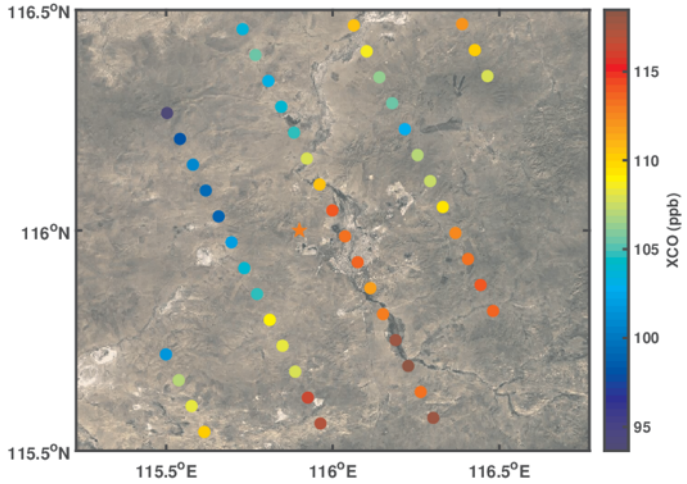
Comparison with OCO-2 ¥ GOSAT ¥ TROPOMI



Aircore vs. OCO-2 on 13th June



Aircore vs. GOSAT on 12th November

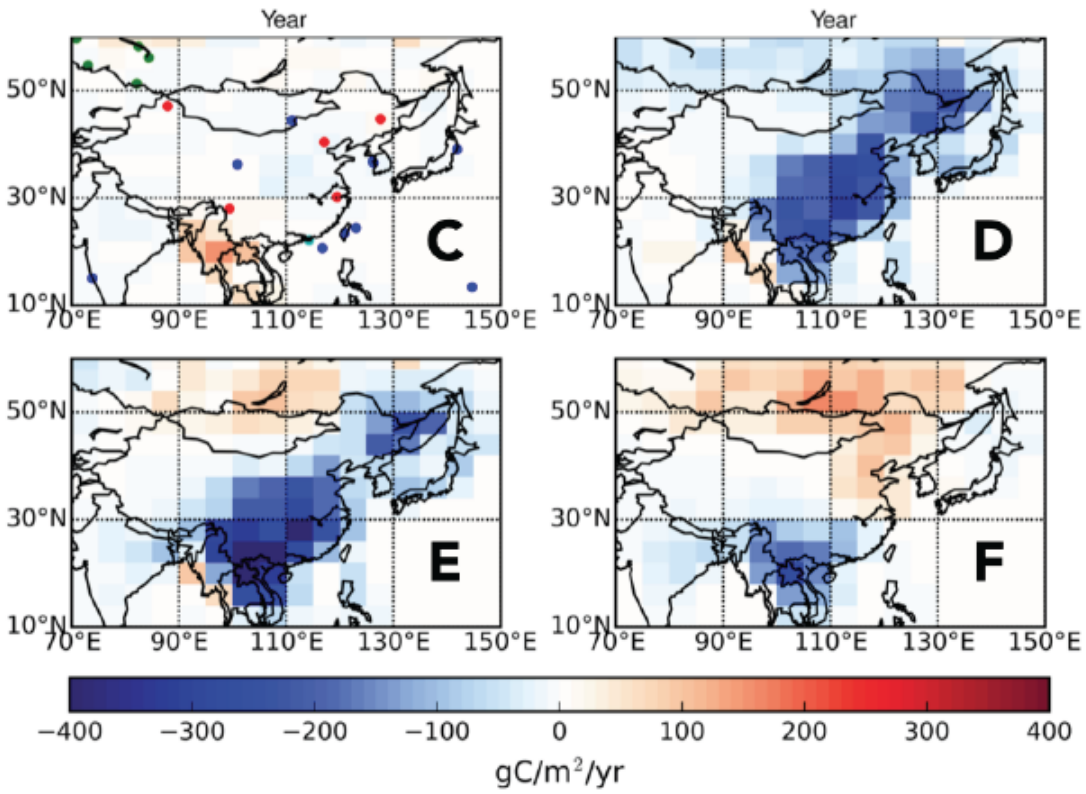


Aircore vs. TROPOMI on 13th June

	CO_2	CO
June campaign		
Aircore	406 ppm	113 ppb
Satellite	405.6 ppm ± 0.6 ppm (OCO-2)	118 ppb ± 1.89 ppb (TROPOMI)
November campaign		
Aircore	406 ppm	82 ppb
Satellite	404.3 ppm (GOSAT)	¥

Carbon flux inversion – ecosystem

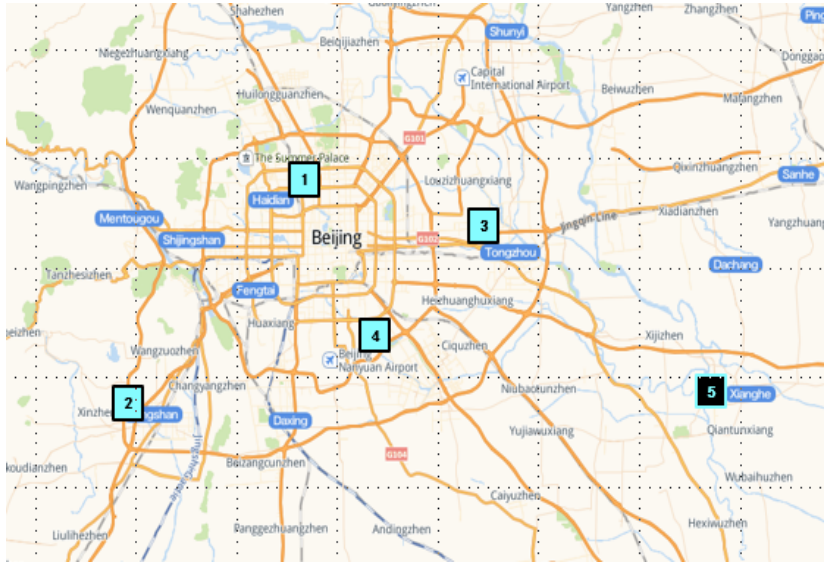
A new insight on the Chinese Carbon sink by combined the satellite data of GOSAT, OCO-2 with in-situ measurements in China.



J. Wang et.al. A larger than expected net Chinese carbon sink inferred from new atmospheric data. *Nature* under review

Carbon flux inversion –urban emissions

Beijing City



Tag	Site name	Latitude(°N)	Longitude(°E)	Altitude(m)
1	Institute of Atmospheric Physics	39.98	116.39	34.0
2	Fangshan Weather Station	39.75	116.14	46.6
3	Tongzhou Weather Station	39.95	116.63	26.0
4	Nanyuan Observatory	39.48	116.28	31.3
5	Xianghe Station	39.80	116.96	20.0

表 1. 观测地点的地理坐标及海拔

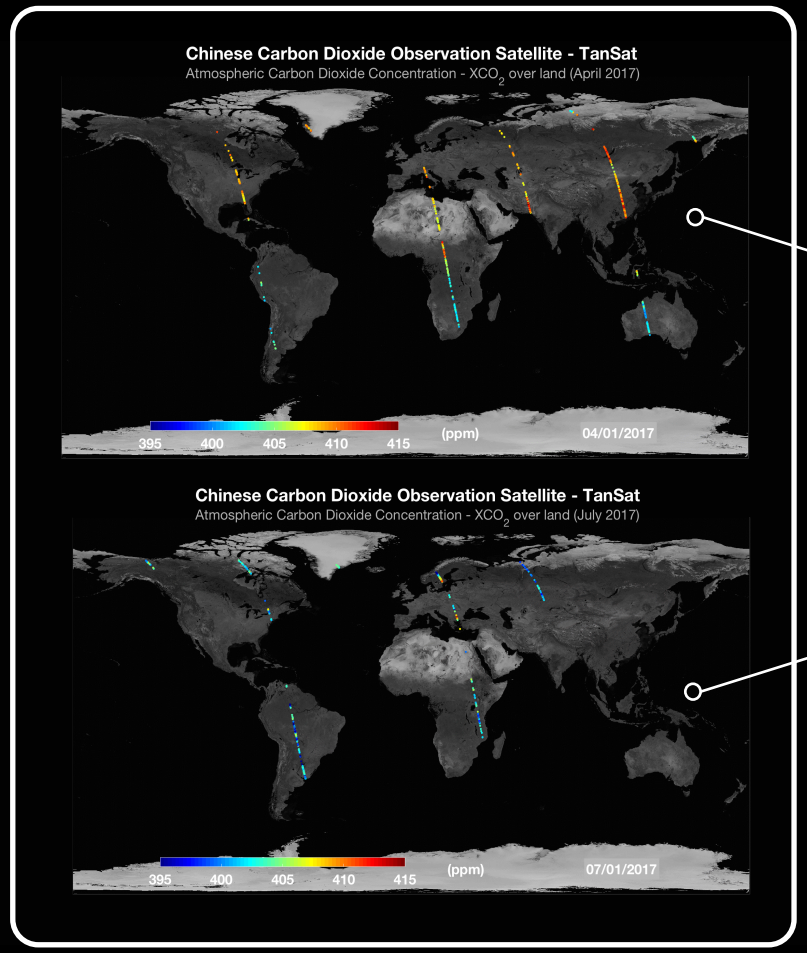
Simultaneous observation with OCO-3 Area mode

Hangzhou City

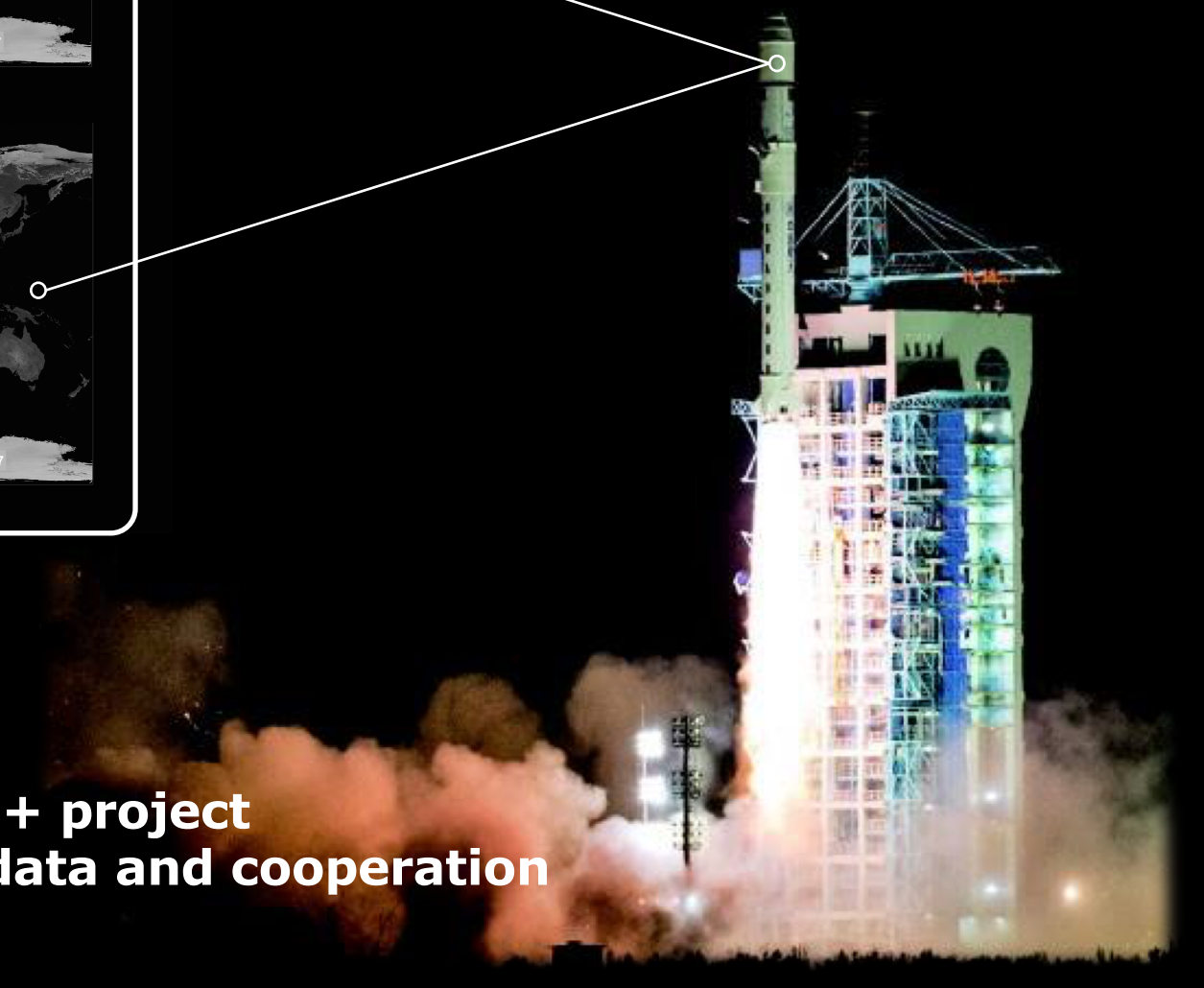
标号	站点名	纬度(°N)	经度(°E)	海拔(m)
1	临安站	120.20	30.50	138.6
2	慢头山本地站	120.10	30.23	41.7
3	余杭区气象局	120.30	30.42	12.0
4	萧山区气象局	120.26	30.18	8.0

Summary and future plan

1. The L2 data have been retrieved by the IAPCAS algorithm and new global data of XCO2 and SIF will be released within 2-3 months.
2. The validation campaign have been conducted and data will be applied to GOSAT, OCO and TROPOMI products validation,
3. Chinese CO2 flux has been estimated by Satellite observation and surface in-situ.
4. Validation campaign will be achieved in China in 2019 and more international cooperation will be promoted.



22 Dec. 2016



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Thank you!