



2022 DRAGON 5 SYMPOSIUM
MID-TERM RESULTS REPORTING
17-21 OCTOBER 2022

A golden dragon illustration, a traditional Chinese symbol, is positioned behind the project title text. The dragon is depicted in a dynamic, coiled pose with its head facing right.

PROJECT ID. 59327
**GROUND-BASED REMOTE SENSING
MEASUREMENTS AT XIANGHE:
DEVELOPMENT AND APPLICATIONS**



20/OCT/2022: 10:20AM-11:50AM · SESSION: VR1 ORAL

ID. 172

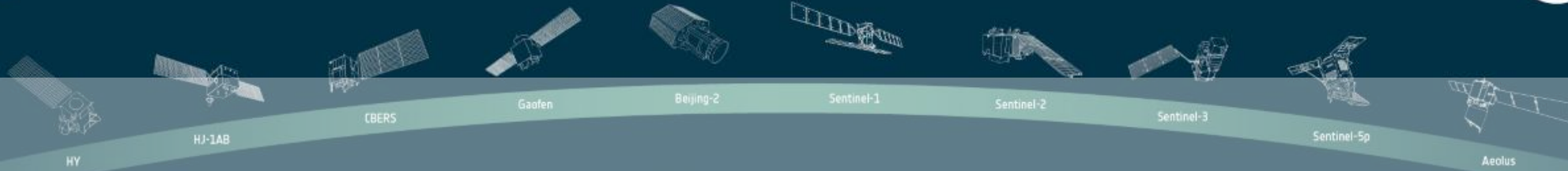
PROJECT TITLE: VALIDATION OF CHINESE CO₂-MEASURING SENSORS AND EUROPEAN TROPOMI/SENTINEL-5 PRECURSOR USING FTIR AND MAX-DOAS DATA AT XIANGHE (VCEX)

PRINCIPAL INVESTIGATORS: DR. BART DILS, PROF. DR. PUCAI WANG

CO-AUTHORS: BART DILS, PUCAI WANG, MINQIANG ZHOU, MICHEL VAN ROOZENDAEL, MARTINE DE MAZIÈRE, MARTINA FRIEDRICH, FRANCOIS HENDRICK, BAVO LANGEROCK, WEIDONG NAN, GAIA PINARDI, MAHESH KUMAR SHA, CORINNE VIGOUROUX, TING WANG

PRESENTED BY: BART DILS





1. BACKGROUND

2. ATMOSPHERIC REMOTE SENSING ACTIVITIES AT XIANGHE

3. VALIDATION ACTIVITIES AT XIANGHE





Royal Belgian
Institute for Space
Aeronomy
Brussels

- UV-VIS DOAS group (Dr. M. Van Roozendael)
- FTIR group (Dr. M. De Mazière)



Institute of Atmospheric
Physics – Chinese Academy of
Sciences
Xianghe

Prof P. Wang





TOTAL CARBON COLUMN OBSERVING NETWORK (TCCON)



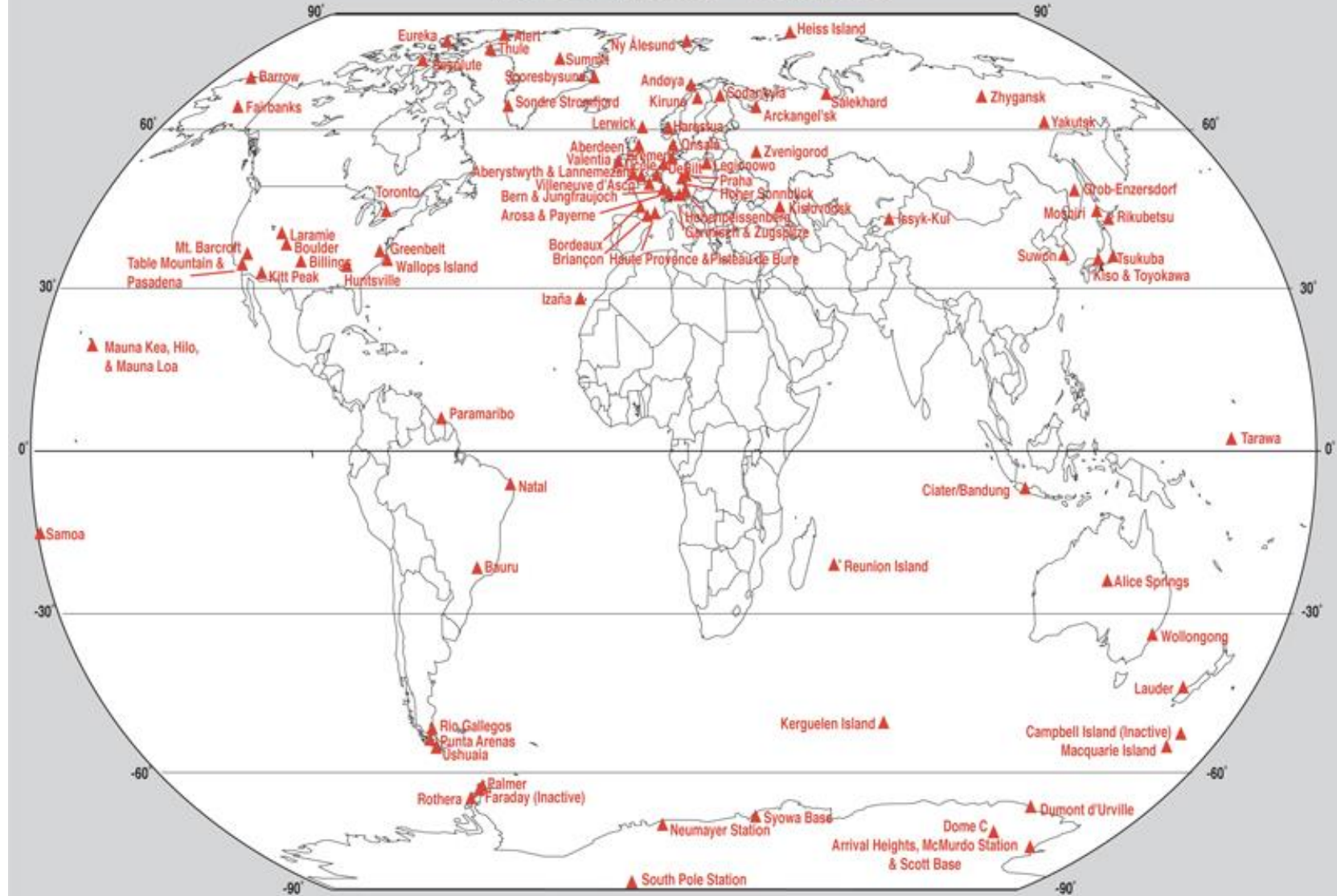
- Snapshot 2008
- Little to no coverage in South America, Africa and mainland Asia

BIRA





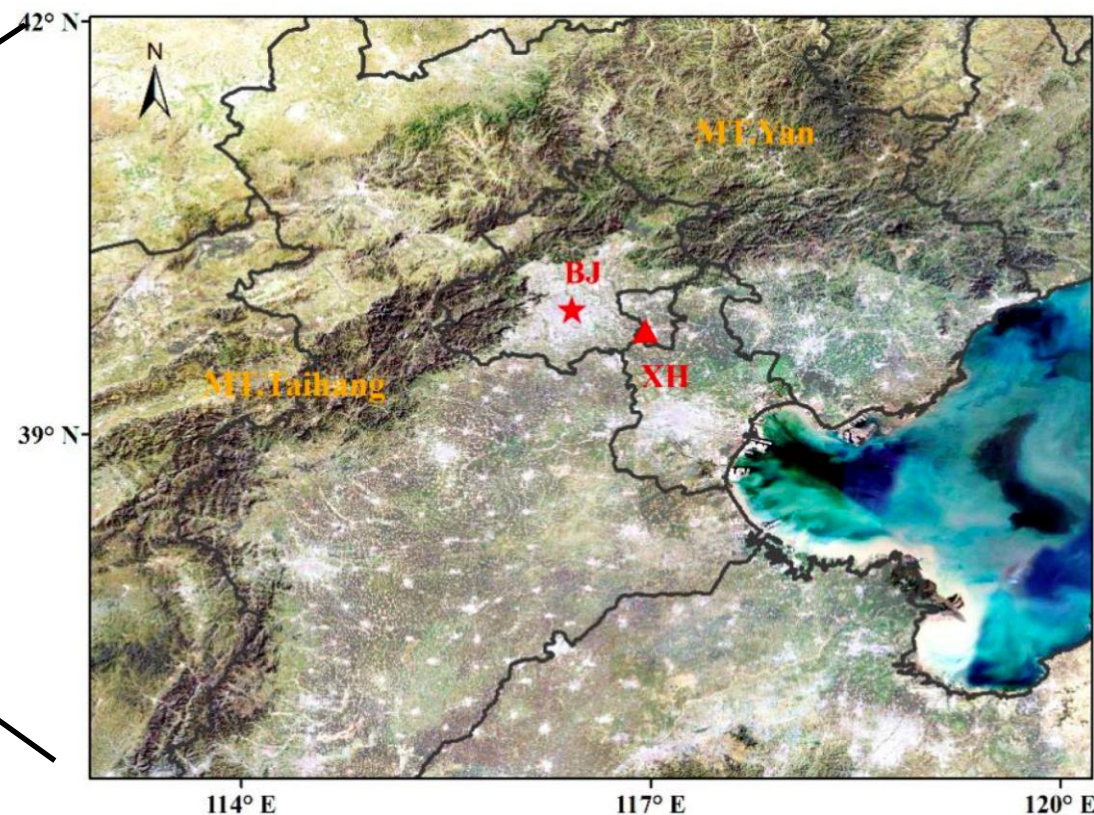
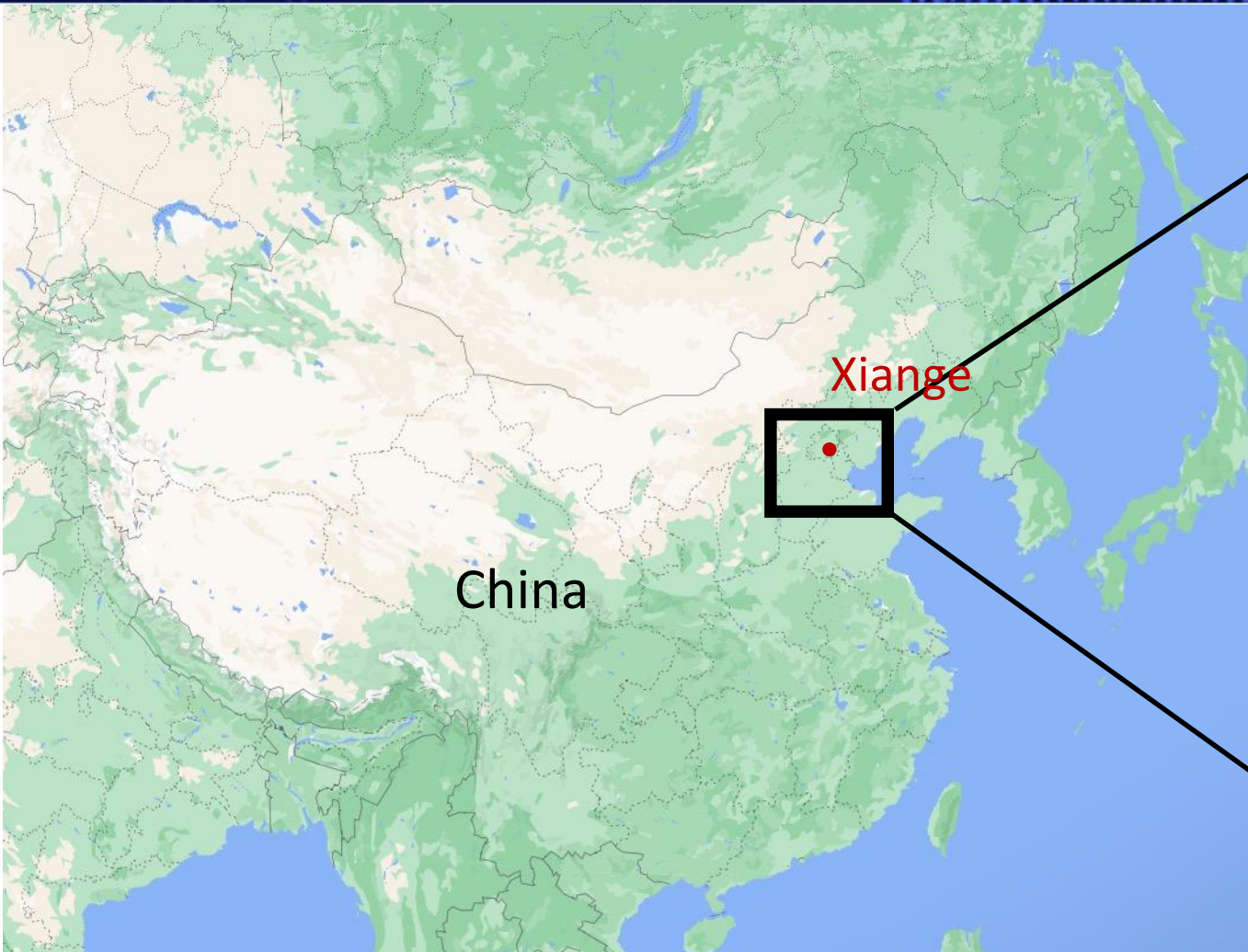
NDACC Sites



Network for the Detection of Atmospheric Composition Change (NDACC)

- Quasi-Global coverage is vital for model assimilation, satellite validation etc
- Strong need for these networks to incorporate sites in China





50km to the east-southeast of Beijing
and 70 km to the north-northwest of Tianjin





BIRA-IASB MAX-DOAS instrument

- 2-channel MAX-DOAS spectrometer developed at BIRA in 2008 and permanently installed in Xianghe in Feb. 2010
- Continuously operated until Aug. 2022 in collaboration with IAP/CAS
- Instrument due to be replaced
- Total columns of O_3 and NO_2
- Tropospheric profiles of NO_2 , HCHO, glyoxal, HONO and SO_2
- Aerosol AOD and extinction profile



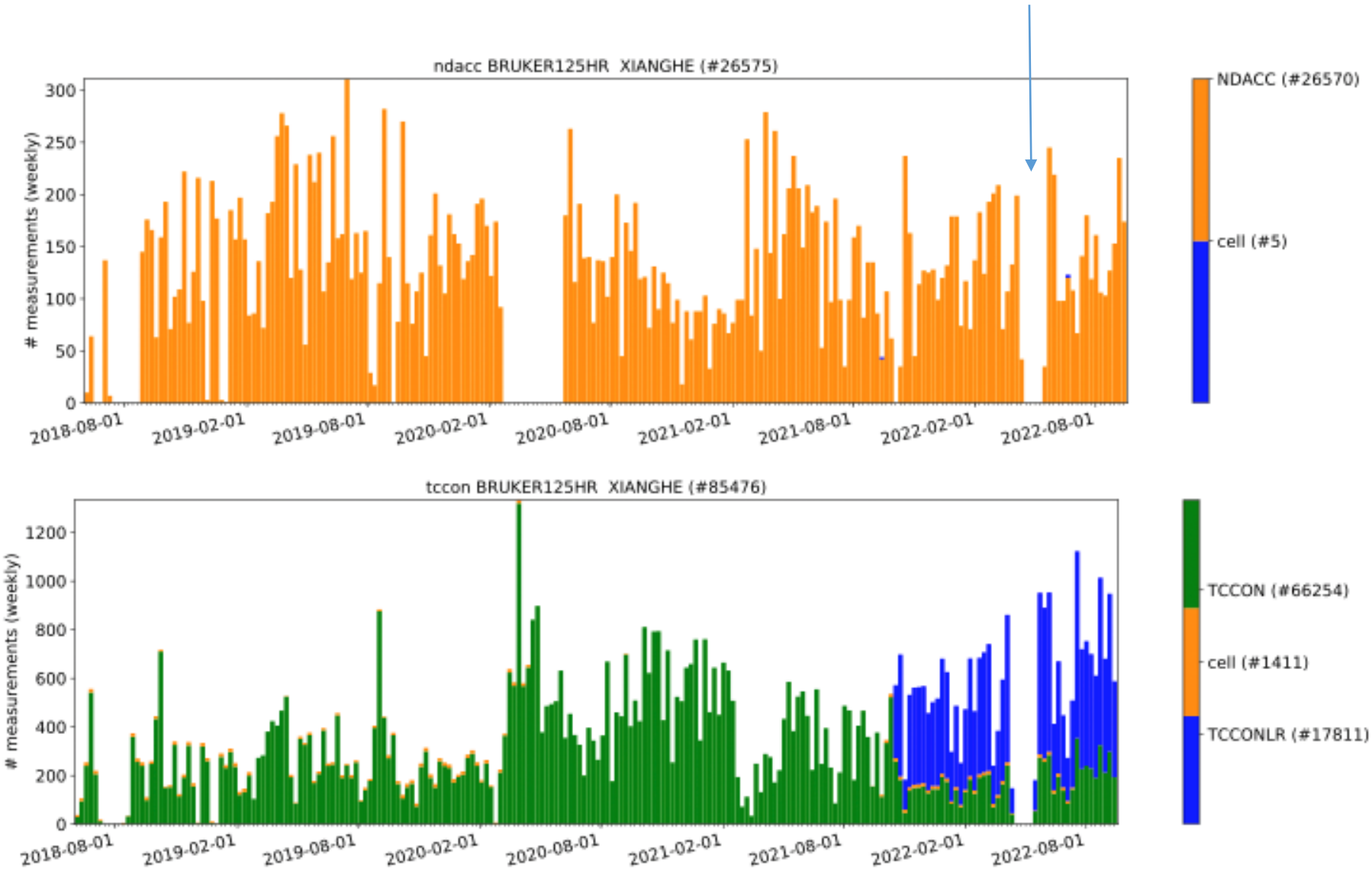


- TCCON type measurements since August 2018
- **Became a formal TCCON site 3 September 2021!**
- Dr. Minqiang ZHOU (ex-BIRA [2015-2021], currently at IAP in the team of Prof. WANG) became a member of the Steering Committee of TCCON on the same day
- 2nd Chinese TCCON site after Hefei (Anhui Institute of Optics and Fine Mechanics (AIOFM), Hefei Institutes of Physical Science) formally a TCCON site since 2018



Current TCCON



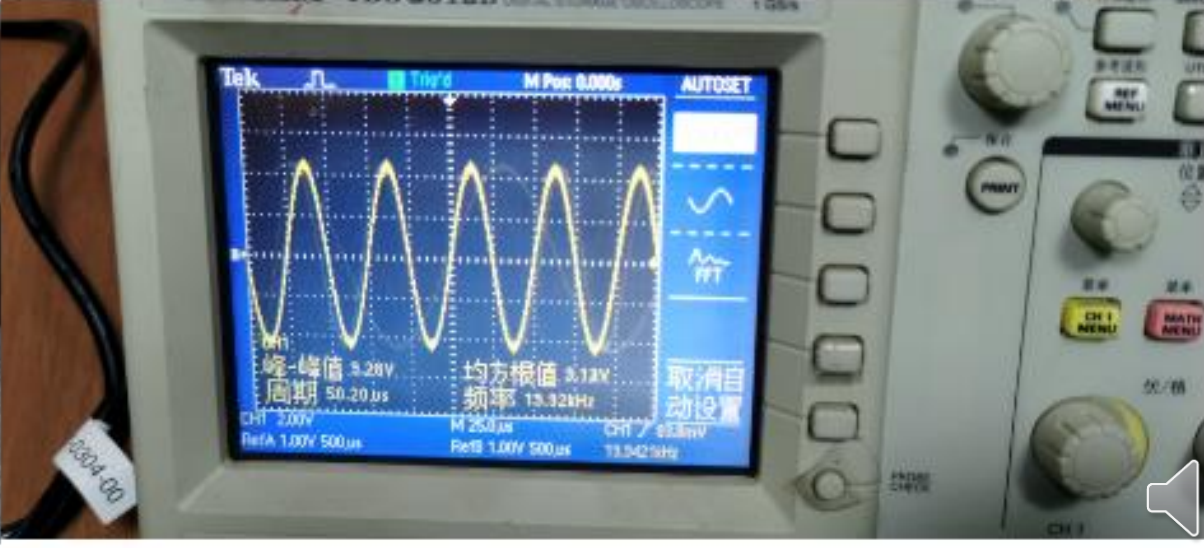
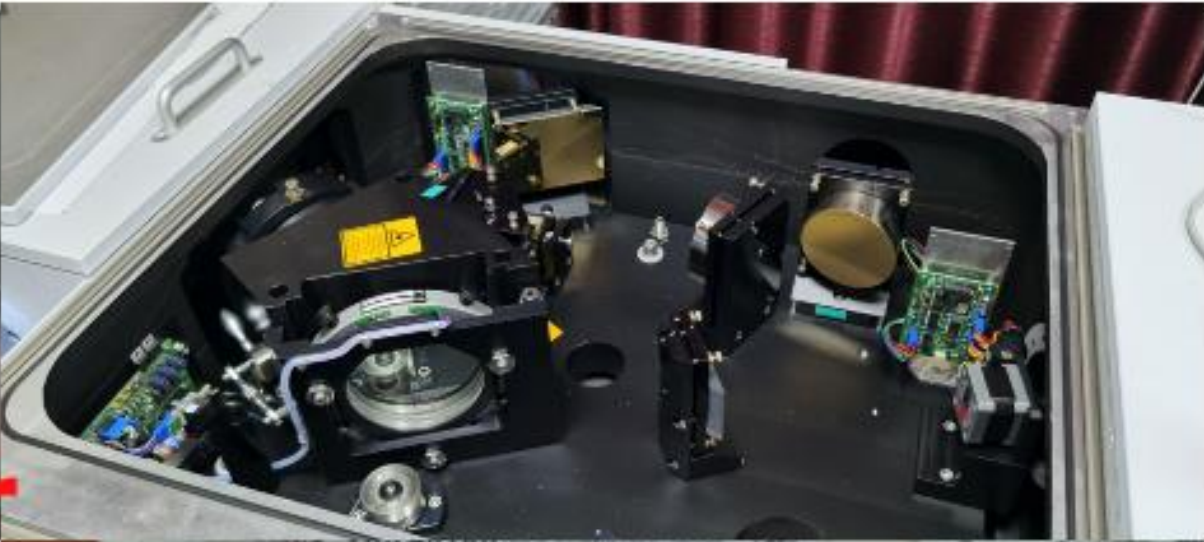


- TCCON – LR mode added since Nov 2011
- ~150 spectra for NDACC per week
- ~ 200 spectra for TCCON per week
- ~ 400 spectra for TCCON- LR per week





LASER replacement for Bruker 125HR instrument



Bruker 125HR FTIR



Pandora



Microwave CIMEL-318



Bruker EM27/SUN



Brewer



MIN-DOAS MAX-DOAS



XIANGHE remote sensing activities affiliated or collaborated with international networks

Instrument	Networks	Status	Instrument note (last year)
Bruker 125HR	TCCON	Operational	Laser down (2 month gap)
Bruker 125HR	NDACC	Application	Laser down (2 month gap)
Bruker EM27/SUN	COCCON	Operational	-
Pandora	PNG	Application	-
Cimel 318	AERONET	Operational	-
Brewer	WMO	Operational	-
MAX-DOAS	NDACC	Operational*	Detector fail since Aug 2022

* Data on NDACC Rapid Delivery site, Consolidated pending



Welcome to the FRM₄DOAS website

Fiducial Reference Measurements (FRM) are a suite of independent, fully characterized, and traceable ground measurements that follow the guidelines outlined by the GEO/CEOS Quality Assurance framework for Earth Observation (see <http://qa4eo.org>). These FRM provide the required confidence in data products, in the form of independent validation results and satellite measurement uncertainty estimation, over the entire end-to-end duration of a satellite mission (more information available [here](#)).

The Fiducial Reference Measurements for Ground-Based DOAS Air-Quality Observations (FRM₄DOAS) is a 2-year ESA project which started in July 2016. It aims at further harmonization of MAX-DOAS systems and data sets, through the

- specification of best practices for instrument operation
- demonstration of a centralised NRT (near-real-time/6-24h latency) processing system for MAX-DOAS instruments operated within the international Network for the Detection of Atmospheric Composition Change (NDACC)
- establishment of links with other UV-Visible instrument networks, e.g. PGN

The target species for the first phase of the project are tropospheric and stratospheric NO₂ vertical profiles, total O₃ columns, and tropospheric HCHO profiles. The aim is to produce homogenous ground-based reference datasets from instruments being operated at long-term monitoring sites (e.g. NDACC) or during field campaigns. Such reference data sets will play a crucial role in the validation of future atmospheric composition satellite missions, in particular the ESA Copernicus Sentinel missions S-5P, S-4, and S-5.



Image courtesy of A. Pitters (KNMI)

The FRM₄DOAS project was funded under the ESA contract n°4000118181/16/I-EF.

- Optimization and standardization of retrieval strategies for NO₂, HCHO, glyoxal and SO₂

Important to have a wide range of stations operating under different conditions!

- Operational centralized processing of Xianghe UV-Vis MAX-DOAS data for NO₂ and HCHO using FRM₄DOAS system
- Exploitation of Xianghe MAX-DOAS data series for the validation of GOME-2, OMI, TROPOMI and GEMS satellite data, with a focus on NO₂, HCHO, glyoxal and SO₂ data products



- Like with MAX-DOAS we see a strong push towards ever more harmonized retrieval strategies

Research article 09 Oct 2020

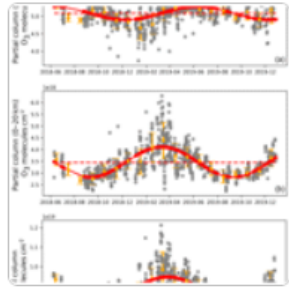
Ground-based Fourier transform infrared (FTIR) O₃ retrievals from the 3040 cm⁻¹ spectral range at Xianghe, China

Minqiang Zhou¹, Pucui Wang^{2,3,4}, Bavo Langerock¹, Corinne Vigouroux¹, Christian Hermans¹, Nicolas Kumps¹, Ting Wang², Yang Yang², Denghui Ji², Liang Ran², Jinqiang Zhang², Françoise Posny⁵, Valentin Duflot^{5,6}, Jean-Marc Metzger⁶, and Martine De Mazancourt⁶

Deriving Temporal and Vertical Distributions of Methane in Xianghe Using Ground-based Fourier Transform Infrared and Gas-analyzer Measurements

Denghui Ji, Minqiang Zhou , Pucui Wang, Yang Yang, Ting Wang, Xiaoyu Sun, Christian Hermans, Bo Yao & Gengchen Wang

Advances in Atmospheric Sciences **37**, 597–607 (2020) | [Cite this article](#)



- Exploitation of Xianghe data for the validation studies



FTIR - TCCON – TROPOMI/OCO

- CO (Sha et al., 2021)
- CH₄ (Sha et al., 2021)
- CO₂ (Zhou et al., 2022)

<https://acp.copernicus.org/articles/21/12561/2021/acp-21-12561-2021.html>

<https://amt.copernicus.org/articles/14/7775/2021/>

FTIR - NDACC – TROPOMI

- HCHO (Vigouroux et al., 2021)
- NO₂ (Vigouroux et al., in preparation)

<https://www.mdpi.com/2072-4292/14/1/214>

<https://amt.copernicus.org/articles/13/3751/2020/amt-13-3751-2020-discussion.html>

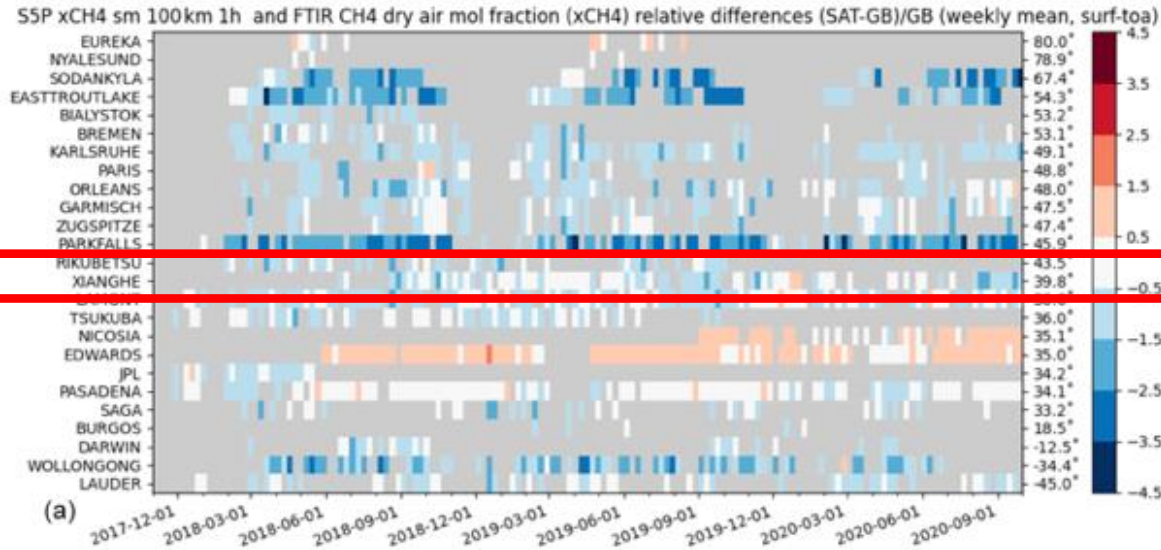
<https://www.mdpi.com/2072-4292/14/15/3769>

DOAS - NDACC – TROPOMI/OMI

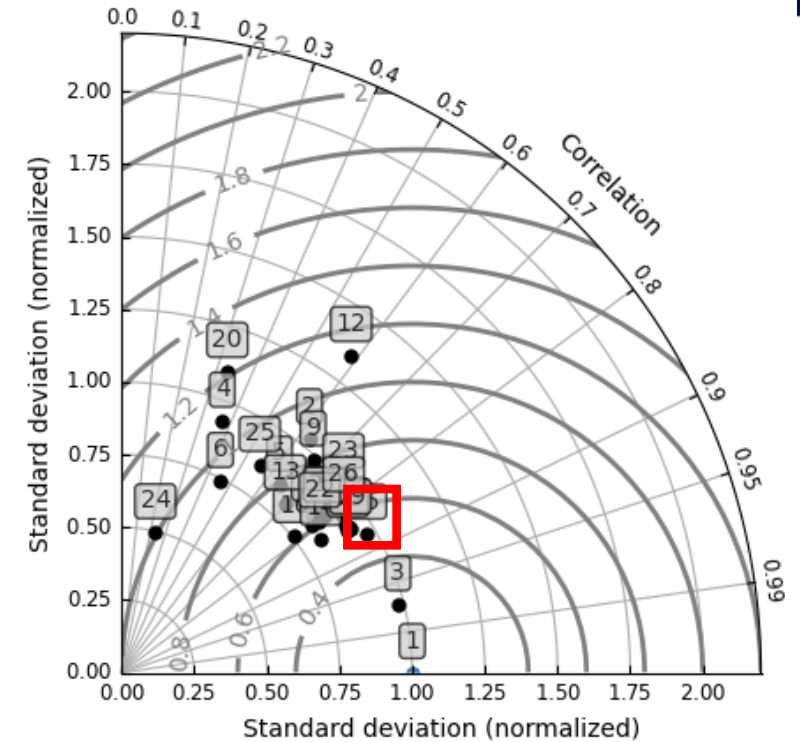
- NO₂ (Wang et al., 2022)
- HCHO (De Smedt et al., 2021)
- CHOCHO (Lerot et al., 2021)

<https://amt.copernicus.org/articles/14/6249/2021/amt-14-6249-2021-discussion.html>





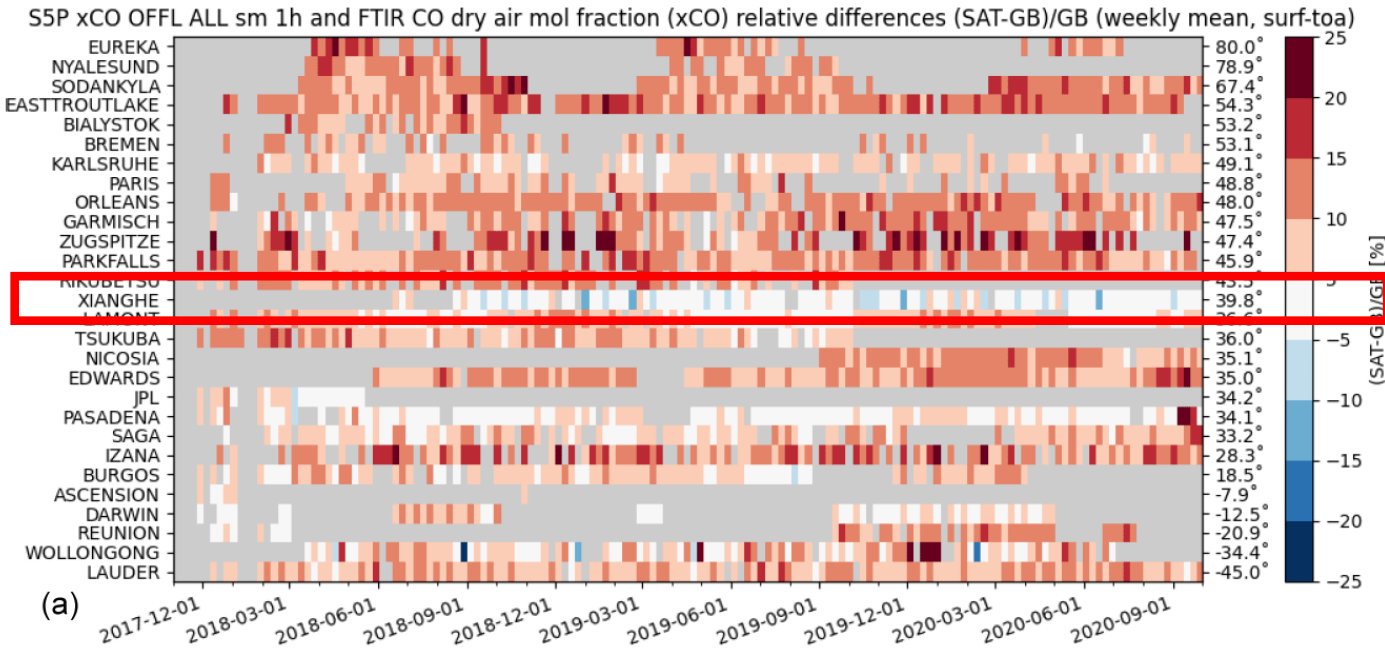
- 1: S5P xCH4 sm 100km bc 1h
- 2: EUREKA (1384)
- 3: NYALESUND (113)
- 4: SODANKYLA (5915)
- 5: EASTTROUTLAKE (12302)
- 6: BIALYSTOK (1821)
- 7: BREMEN (1150)
- 8: KARLSRUHE (4592)
- 9: PARIS (4999)
- 10: ORLEANS (5984)
- 11: GARMISCH (3149)
- 12: ZUGSPITZE (578)
- 13: PARKFALLS (7201)
- 14: RIKUBETSU (18466)
- 15: XIANGHE (4395)
- 16: EDWARDS (24350)
- 17: TSUKUBA (4655)
- 18: NICOSIA (3414)
- 19: EDWARDS (24350)
- 20: JPL (3233)
- 21: PASADENA (20646)
- 22: SAGA (2539)
- 23: BURGOS (417)
- 24: DARWIN (3598)
- 25: WOLLONGONG (4765)
- 26: LAUDER (6708)



Overall:

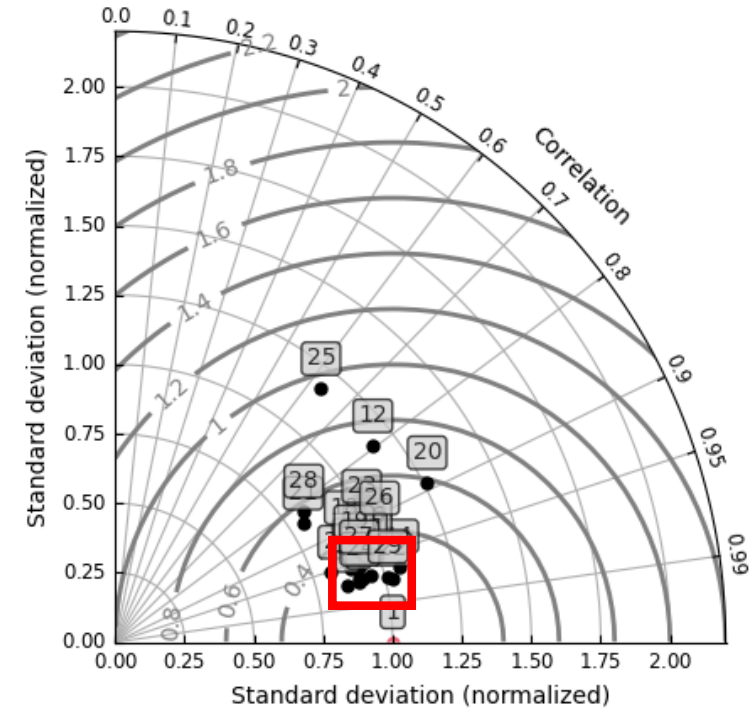
- Small mean bias $< 0.5\%$
- Consistent: no seasonal variation in bias
- Good correlation $R > 0.8$
- Stds observed by sat and g-b are in the same order





1: S5P xCO OFFL ALL sm 1h

- 2: EUREKA (11114)
- 3: NYALESUND (9495)
- 4: SODANKYLA (19439)
- 5: EASTTROUTLAKE (31198)
- 6: BIALYSTOK (4698)
- 7: BREMEN (1671)
- 8: KARLSRUHE (8593)
- 9: PARIS (12139)
- 10: ORLEANS (11147)
- 11: GARMISCH (8325)
- 12: ZUGSPITZE (1887)
- 13: PARKFALLS (16796)
- 14: LAMONT (13655)
- 15: XIANGHE (11349)
- 16: LAMONT (13655)
- 17: TSUKUBA (10467)
- 18: NICOSIA (10668)
- 19: EDWARDS (34554)
- 20: JPL (4951)
- 21: PASADENA (30819)
- 22: SAGA (16583)
- 23: IZANA (8715)
- 24: BURGOS (18581)
- 25: ASCENSION (406)
- 26: DARWIN (9292)
- 27: REUNION (4045)
- 28: WOLLONGONG (10479)
- 29: LAUDER (29781)

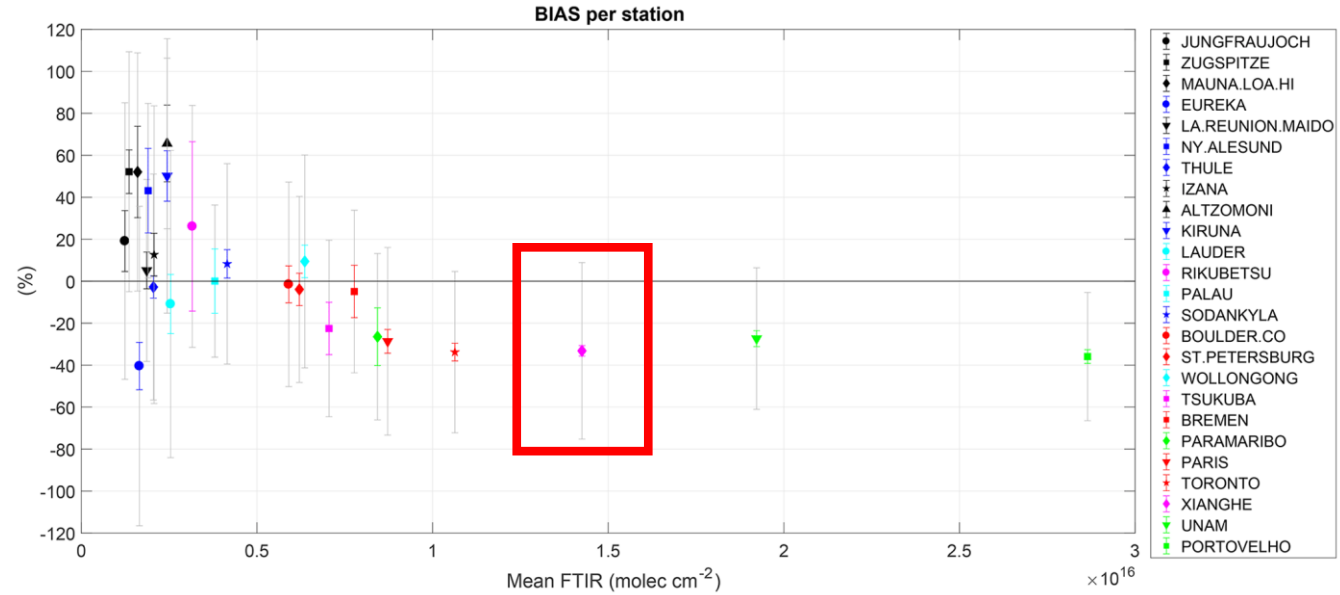
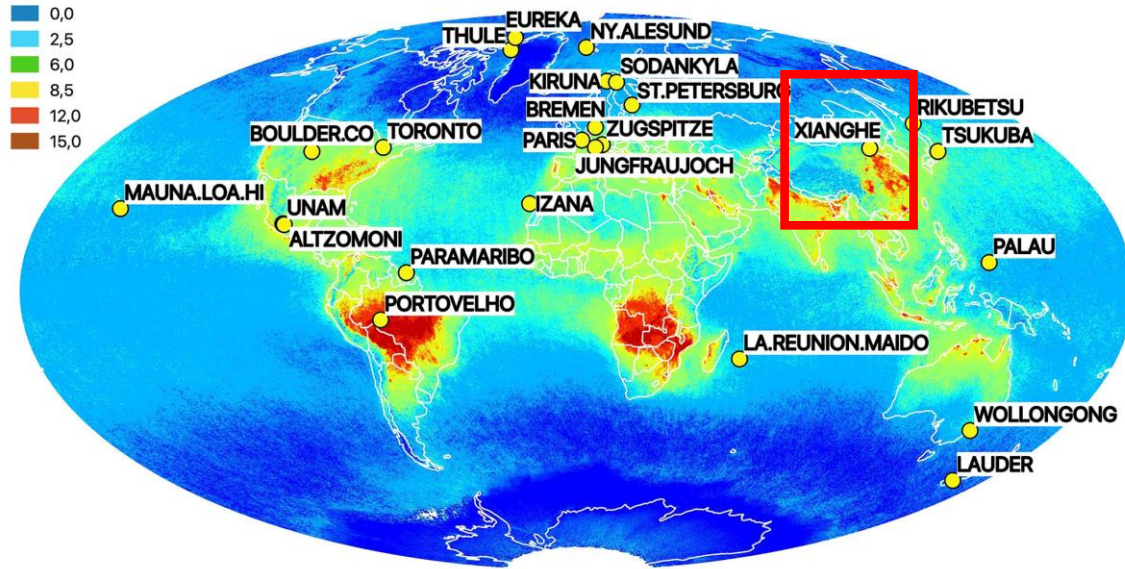


Overall:

- One of the two megacity sites (Xianghe and Pasadena) show smallest bias
- Consistent: no seasonal variation in bias
- Good correlation $R > 0.95$
- Stds observed by sat and g-b are in the same order

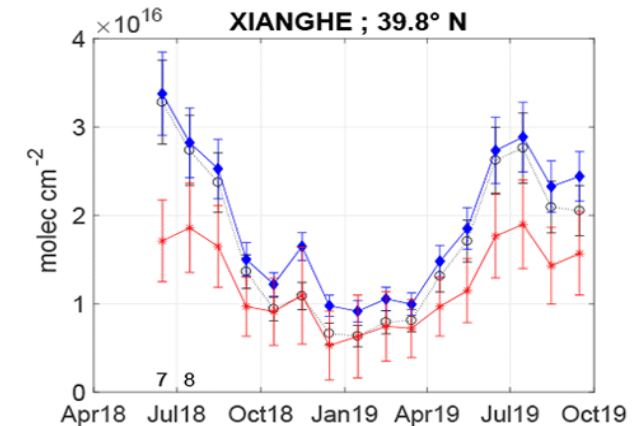


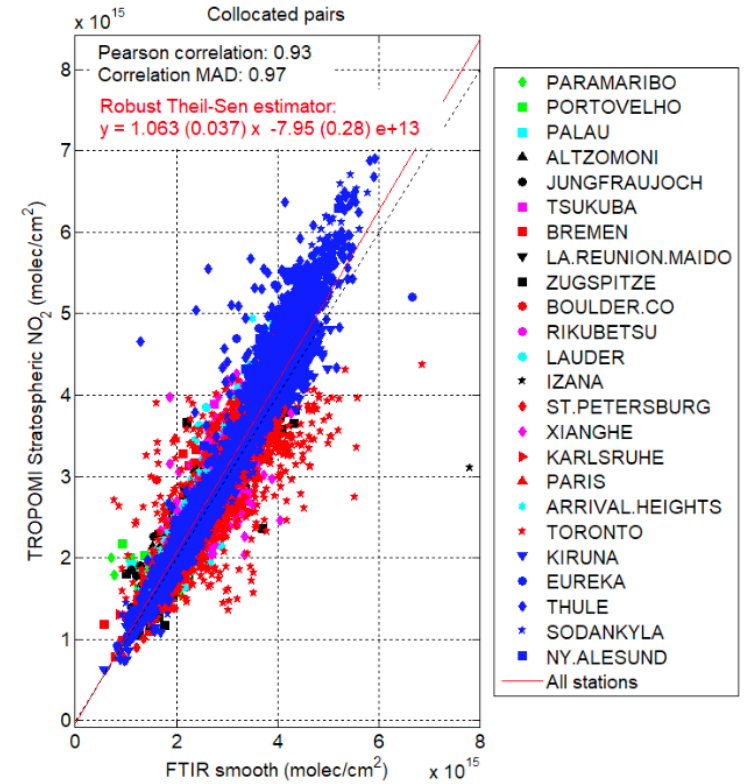
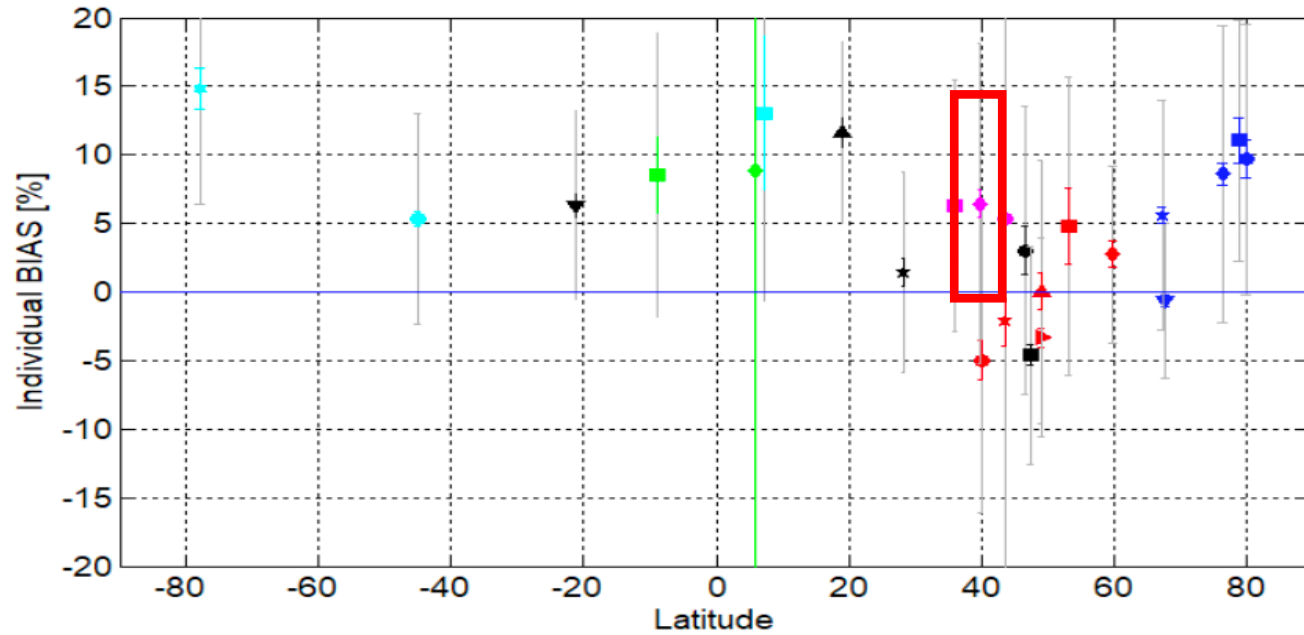
HCHO tropospheric column
x10¹⁵ molec cm⁻²



Overall:

- Typical urban high HCHO site
- Xianghe shows that TROPOMI has a underestimation when HCHO is high
- Good correlation R>0.9
- Same seasonal variation

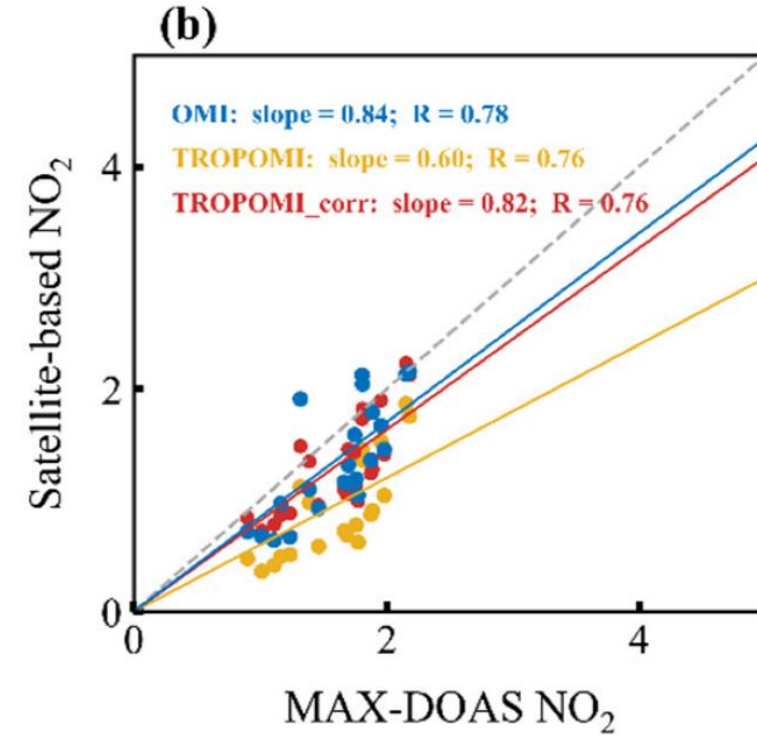
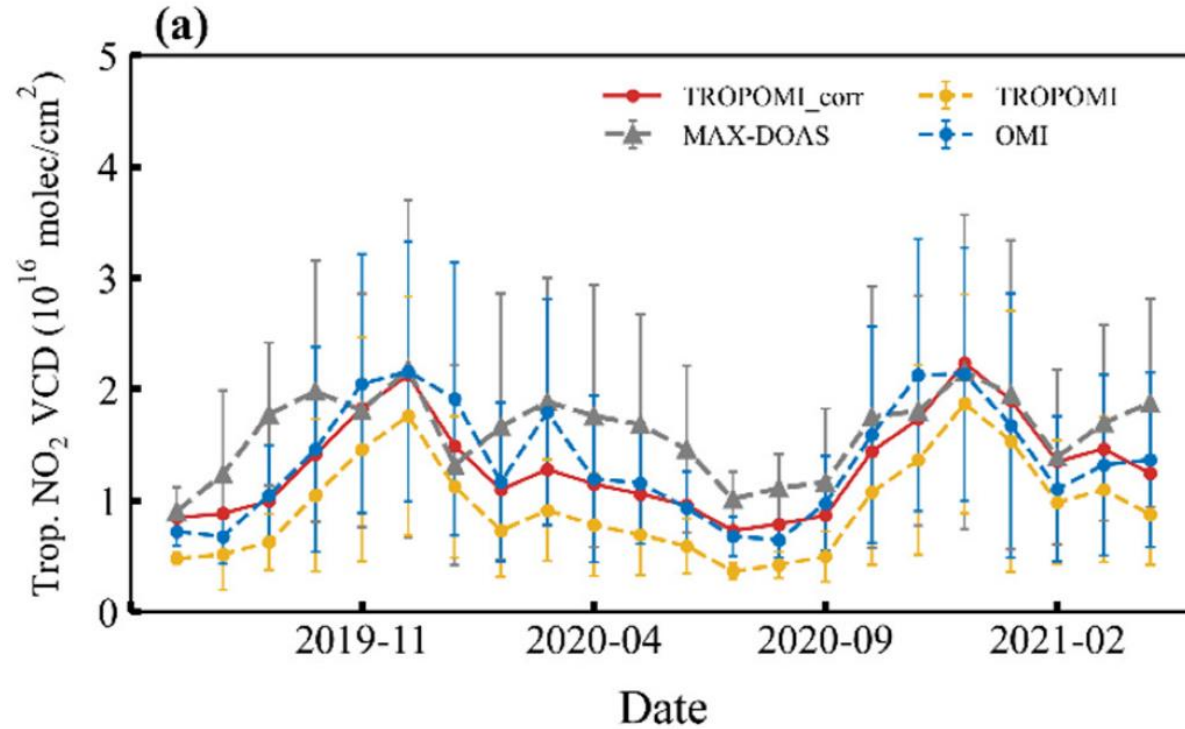




Overall:

- Typical northern-hemisphere mid-latitude site;
- mainly from the stratospheric partial columns
- The mean bias is close to what we see at Xianghe

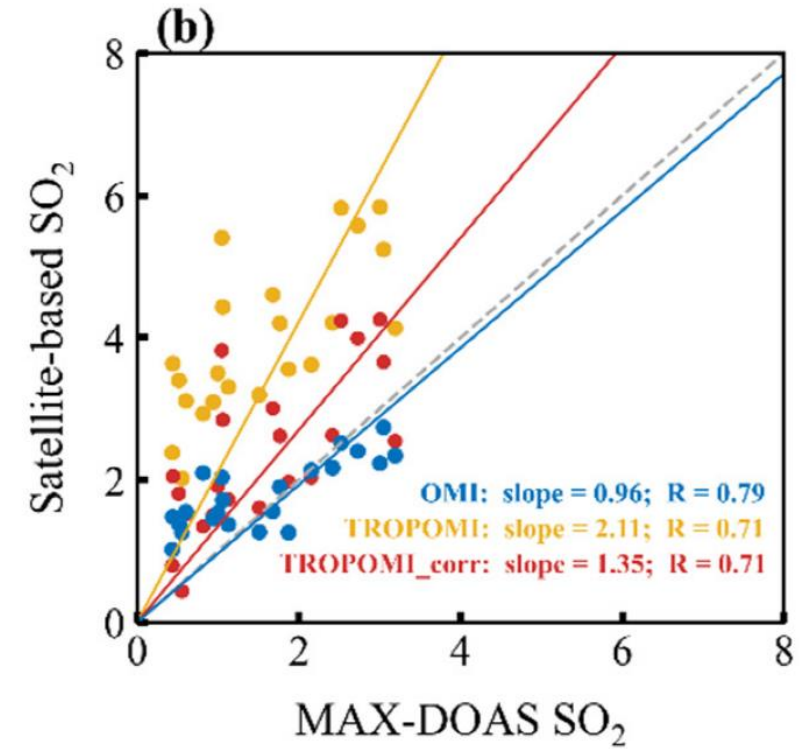
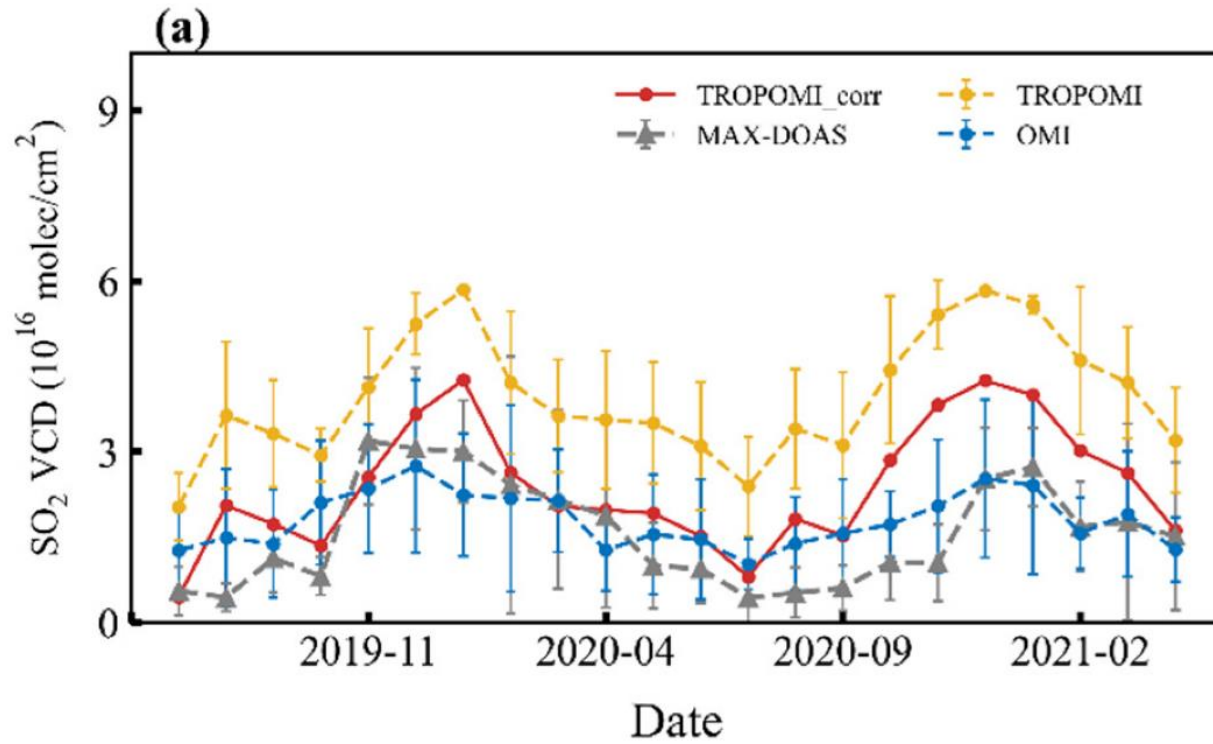




Overall:

- Similar seasonal variation observed by MAX-DOAS, OMI, TROPOMI
- MAX-DOAS is close to OMI, but TROPOMI NO₂ is underestimated

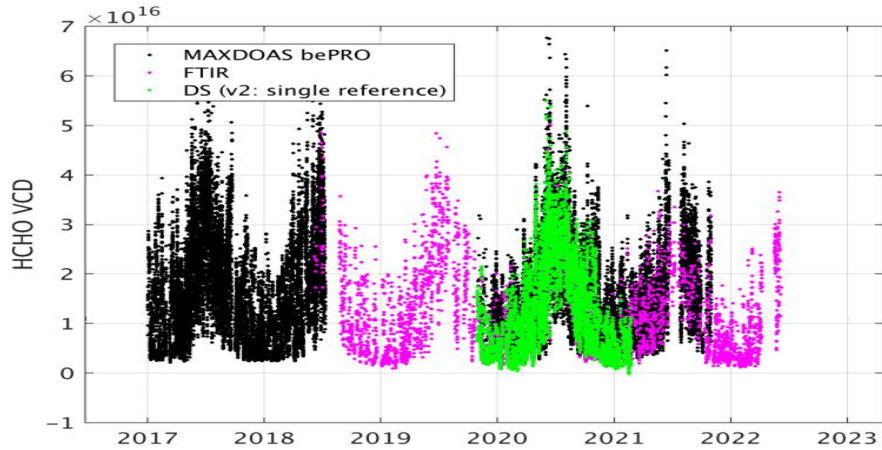




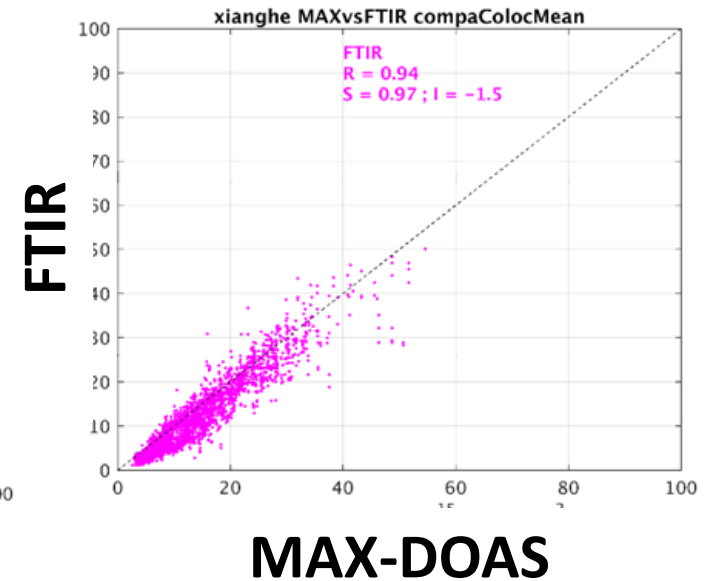
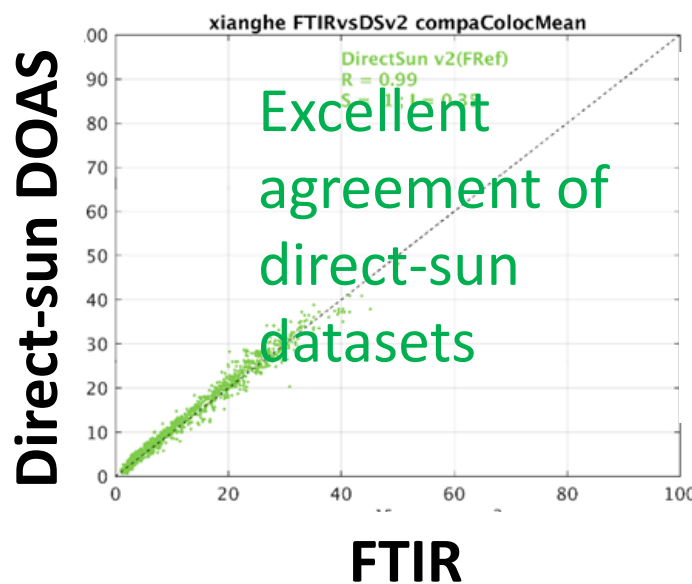
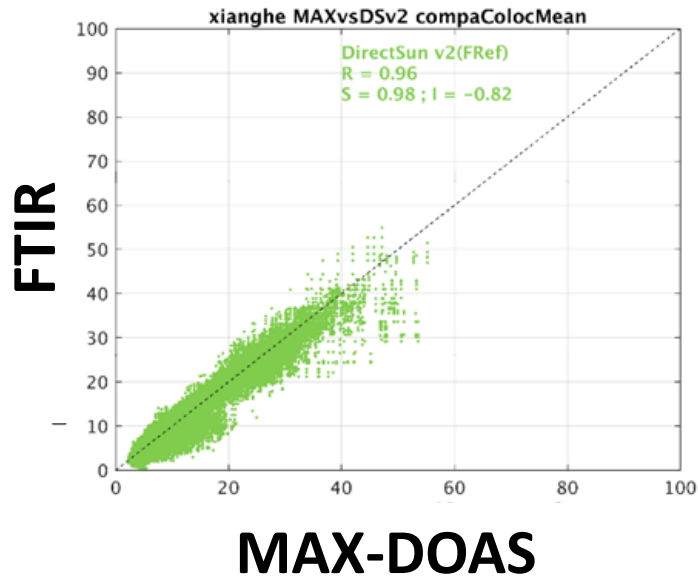
Overall:

- Similar seasonal variation observed by MAX-DOAS, OMI, TROPOMI
- MAX-DOAS is close to OMI, but TROPOMI SO₂ is overestimated





Instrument, processing	Time Period and sampling	viewing direction	Retrieval details
MAX-DOAS	(Since 2010) 1/2017-10/2021 (gap between 7/2018 and 10/2019)	Up to 2018: 165° azimuth After 11/2019: -1° azimuth	bePRO OEM retrieval Clémer et al., 2010; Vlemmix et al., 2015
FTIR	06/2018-6/2022	Pointing the sun	Vigouroux et al., 2018
DirectSun	11/2019-2/2021*	Pointing the sun	Fitting interval: 324.5-359 nm





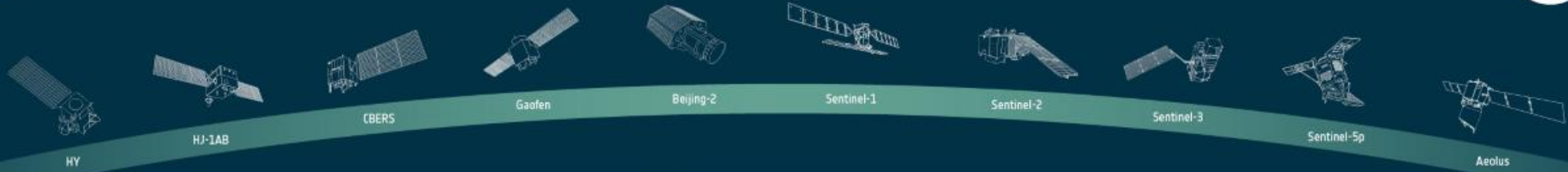
- The Xianghe site is a very important component within the global ground-based remote sensing landscape
 - Under-sampled region
 - Close to a mega-city (rare)
- It has proven to be able to measure high-quality data over prolonged periods of time
- Used within a validation context it has already provided very useful information to algorithm developers to improve their products



- Replace the MAX-DOAS instrument at XIANGHE
- Continue providing high quality data to TCCON
- Continue performing NDACC type FTIR measurements

- Xianghe's official TCCON status, clears it for use in validation studies within projects such as CCI-GHG+, CAMS, etc.





Thank you for your attention

