中国科学院
CHINESE ACADEMY OF SCIENCES

The next generation of Chinese gas monitoring satellite mission

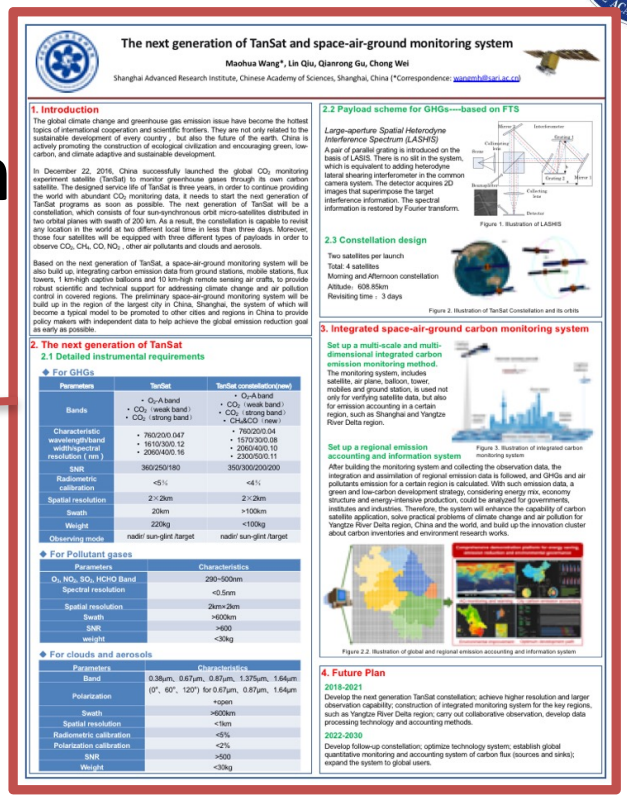
Dongxu Yang, Yi Liu, Zhaonan Cai

Maohua Wang, Lin Qiu,

Zengshan Yin, Longfei Tian,

TanSat-2 team

- *Institute of Atmospheric Physics, CAS*
- *Shanghai Advanced Research Institute, CAS*
- *Innovation Research Institute of Micro-Satellite, CAS*
- *ShanghaiTech University*



The next generation of TanSat and space-air-ground monitoring system

Maohua Wang*, Lin Qiu, Qianrong Gu, Chong Wei

Shanghai Advanced Research Institute, Chinese Academy of Sciences, Shanghai, China (*Correspondence: wangmh@sari.ac.cn)

1. Introduction

The global climate change and greenhouse gas emission issue have become the hottest topics of international cooperation and scientific frontiers. They are not only related to the sustainable development of every country , but also the future of the earth. China is actively promoting the construction of ecological civilization and encouraging green, low-carbon, and climate adaptive and sustainable development.

In December 22, 2016, China successfully launched the global CO_2 monitoring experiment satellite (TanSat) to monitor greenhouse gases through its own carbon satellite. The designed service life of TanSat is three years, in order to continue providing the world with abundant CO_2 monitoring data, it needs to start the next generation of TanSat programs as soon as possible. The next generation of TanSat will be a constellation, which consists of four sun-synchronous orbit micro-satellites distributed in two orbital planes with swath of 200 km. As a result, the constellation is capable to revisit any location in the world at two different local time in less than three days. Moreover, those four satellites will be equipped with three different types of payloads in order to observe CO_2, CH_4, CO, NO_2 , other air pollutants and clouds and aerosols.

Based on the next generation of TanSat, a space-air-ground monitoring system will be also build up, integrating carbon emission data from ground stations, mobile stations, flux towers, 1 km-high captive balloons and 10 km-high remote sensing air crafts, to provide robust scientific and technical support for addressing climate change and air pollution control in covered regions. The preliminary space-air-ground monitoring system will be build up in the region of the largest city in China, Shanghai, the system of which will become a typical model to be promoted to other cities and regions in China to provide policy makers with independent data to help achieve the global emission reduction goal as early as possible.

2. The next generation of TanSat

2.1 Detailed instrumental requirements

◆ For GHGs

Parameters	TanSat	TanSat constellation(new)
Bands	• O_2-A band • CO_2（weak band） • CO_2（strong band）	• O_2-A band • CO_2（weak band） • CO_2（strong band） • CH_4&CO（new）
Characteristic wavelength/band width/spectral resolution（nm）	• 760/20/0.047 • 1610/30/0.12 • 2060/40/0.16	• 760/20/0.04 • 1570/30/0.08 • 2060/40/0.10 • 2300/50/0.11
SNR	360/250/180	350/300/200/200
Radiometric calibration	<5%	<4%
Spatial resolution	2×2km	2×2km
Swath	20km	>100km
Weight	220kg	<100kg
Observing mode	nadir/ sun-glint /target	nadir/ sun-glint /target

◆ For Pollutant gases

Parameters	Characteristics
O_3, NO_2, SO_2, HCHO Band	290~500nm
Spectral resolution	<0.5nm
Spatial resolution	2km×2km
Swath	>600km
SNR	>400
weight	<30kg

◆ For clouds and aerosols

Parameters	Characteristics
Band	0.38μm、0.67μm、0.87μm、1.375μm、1.64μm
Polarization	(0°、60°、120°) for 0.67μm、0.87μm、1.64μm
	+open
Swath	>600km
Spatial resolution	<1km
Radiometric calibration	<5%
Polarization calibration	<2%
SNR	>500
Weight	<30kg

2.2 Payload scheme for GHGs----based on FTS

Large-aperture Spatial Heterodyne Interferometer Spectrum (LASHIS)

A pair of parallel grating is introduced on the basis of LASIS. There is no slit in the system, which is equivalent to adding heterodyne lateral shearing interferometer in the common camera system. The detector acquires 2D images that superimpose the target interference information. The spectral information is restored by Fourier transform.

Figure 1. Illustration of LASHIS

2.3 Constellation design

Two satellites per launch
Total: 4 satellites
Morning and Afternoon constellation
Altitude：608.85km
Revisiting time：3 days

Figure 2. Illustration of TanSat Constellation and its orbits

3. Integrated space-air-ground carbon monitoring system

Set up a multi-scale and multi-dimensional integrated carbon emission monitoring method.

The monitoring system, includes satellite, air plane, balloon, tower, mobiles and ground station, is used not only for verifying satellite data, but also for emission accounting in a certain region, such as Shanghai and Yangtze River Delta region.

Figure 3. Illustration of integrated carbon monitoring system

Set up a regional emission accounting and information system

After building the monitoring system and collecting the observation data, the integration and assimilation of regional emission data is followed, and GHGs and air pollutants emission for a certain region is calculated. With such emission data, a green and low-carbon development strategy, considering energy mix, economy structure and energy-intensive production, could be analyzed for governments, institutes and industries. Therefore, the system will enhance the capability of carbon satellite application, solve practical problems of climate change and air pollution for Yangtze River Delta region, China and the world, and build up the innovation cluster about carbon inventories and environment research works.

Figure 2.2. Illustration of global and regional emission accounting and information system

4. Future Plan

2018-2021

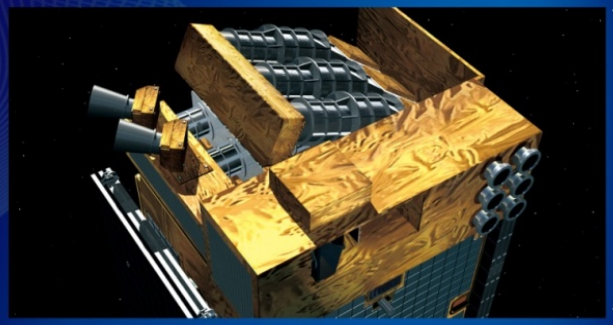
Develop the next generation TanSat constellation; achieve higher resolution and larger observation capability; construction of integrated monitoring system for the key regions, such as Yangtze River Delta region; carry out collaborative observation, develop data processing technology and accounting methods.

2022-2030

Develop follow-up constellation; optimize technology system; establish global quantitative monitoring and accounting system of carbon flux (sources and sinks); expand the system to global users.

TanSat

Global CO2 observation and monitoring



Payload: integrated design, including two scientific instruments

CO2 Sounder

3 bands: 0.758 – 0.778 μm 1.594 – 1.624 μm 2.042 – 2.082 μm
Spectral resolution: < 0.044 / 0.081 / 0.103 nm @ 3 bands respectively
SNR: > 360 / 250 /180 @ 3 bands respectively
Space resolution: 2km×1km
Swath: 20km

Cloud and Aerosol Polarimetry Imager:

5 bands: 0.38/0.67/0.87/1.375/1.64 μm
Polarization measurement: 0 °& 60°& 120° @ 0.67/1.64 μm
Space resolution: 500m
Swath: 400km

Observation mode:

Nadir mode: High resolution observation over the land
Sun-glint model: High SNR observation over the sea
Target mode: Observation to specific surface targets, such as ground-based validation sites

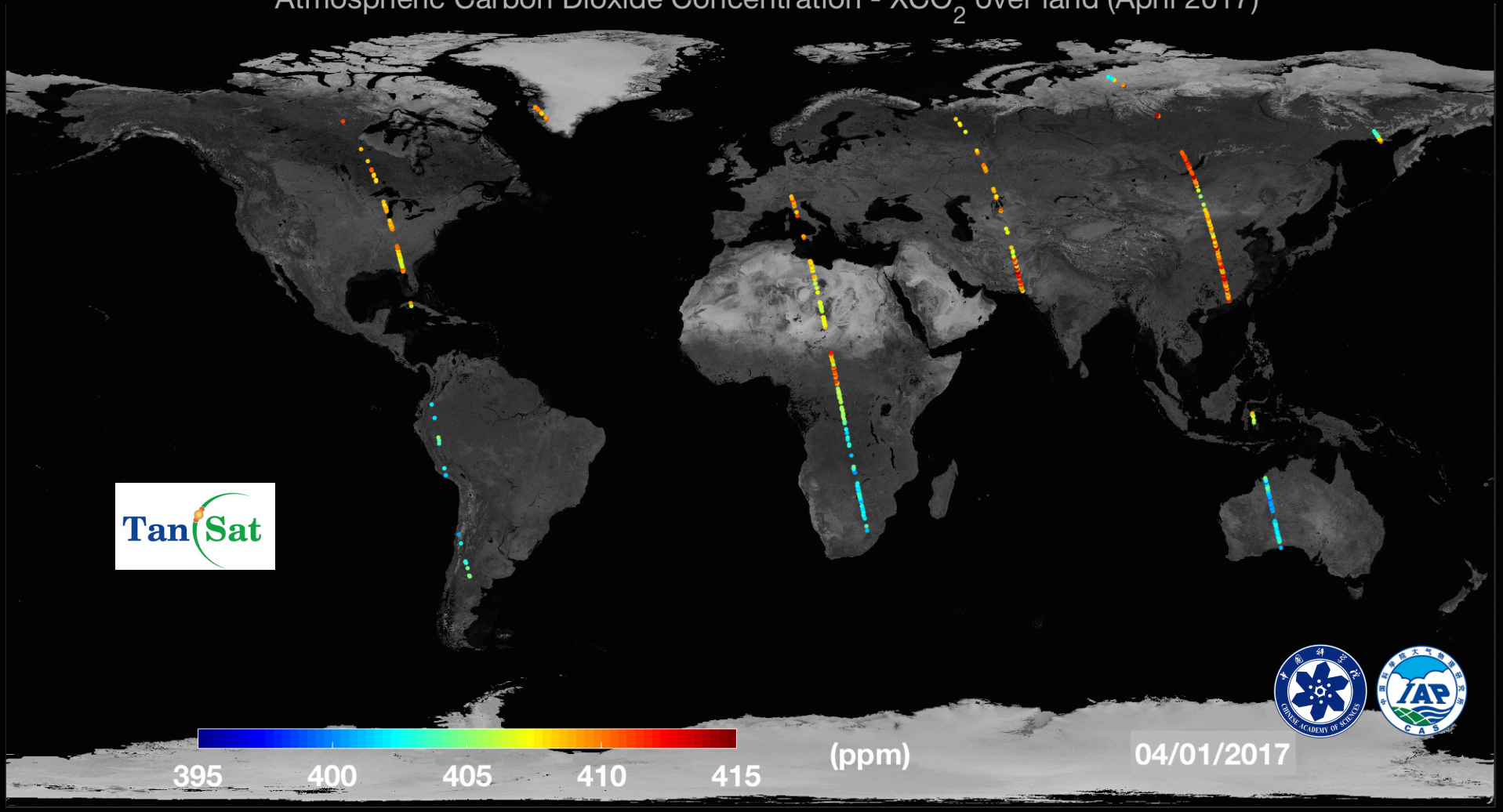

Nadir mode

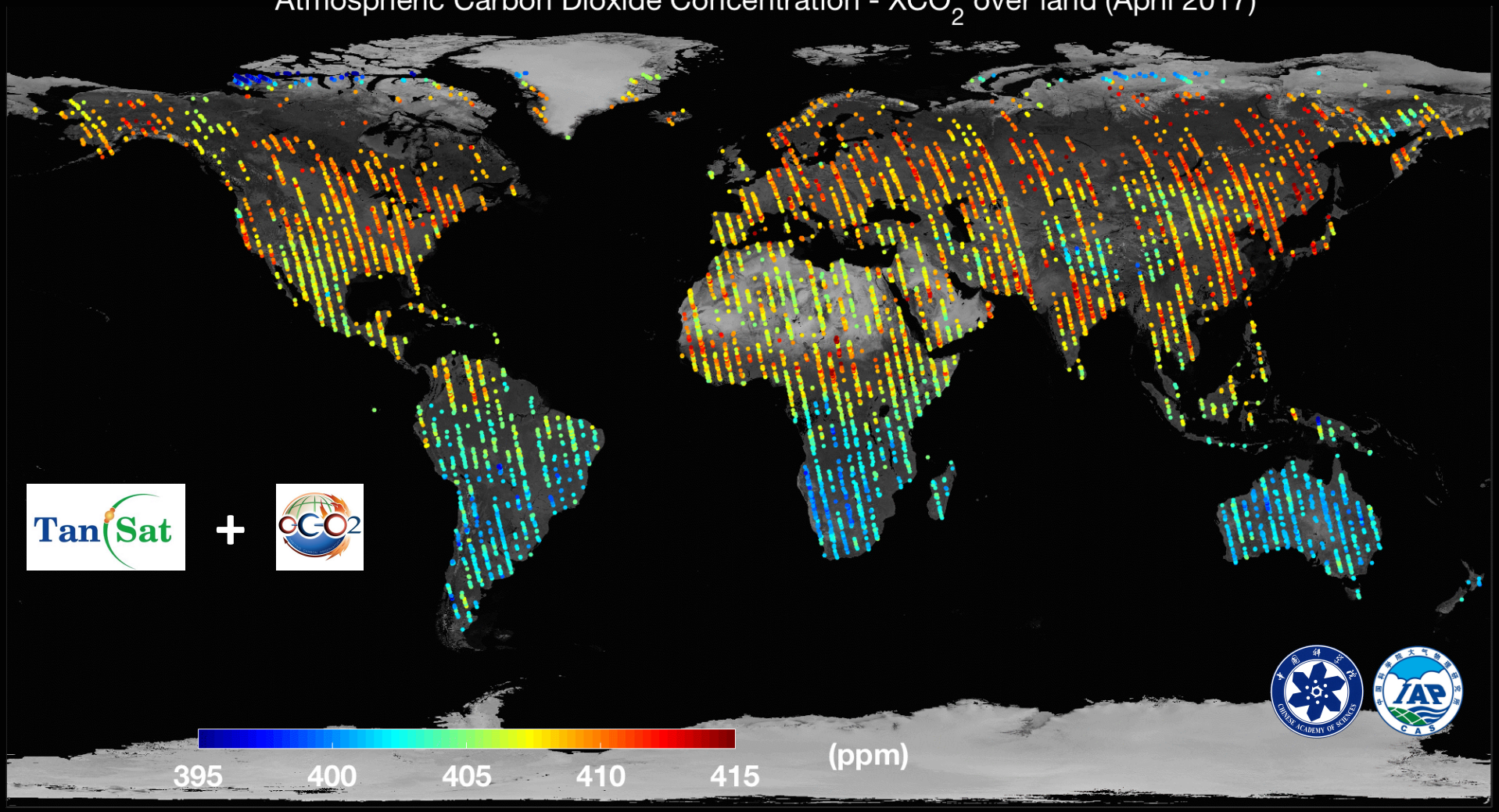

Sun-glint mode


Target mode

Chinese Carbon Dioxide Observation Satellite - TanSat

Atmospheric Carbon Dioxide Concentration - XCO_2 over land (April 2017)




Atmospheric Carbon Dioxide Concentration - XCO2 over land (April 2017)
TanSat
+
OCO2
395
400
405
410
415
(ppm)

GHGs missions: Big family

Mission	nationality	Launching	Orbit	Weight	Precision	Swath	Footprint
SCIAMACHY	EU	2002	772km	8211kg	16	1000km	32×215 km²
GOSAT（FTS）	Japan	2009	666km	1750kg	<4	N/A（640km）	φ10.5km
OCO-2	U.S.	2014	705km	449kg	1	10.6 km	1.29×2.25 km²
TanSat	China	2016	700km	650kg	1~4	20km	1×2 km²
FY-3D（FTS）	China	2017	836.4km	N/A	1~4	>100km	φ1km
GF-5（SHS）	China	2017	708km	125kg	1~4	N/A（800km）	φ10.5km
GOSAT-2	Japan	2018	613km	2000kg	1	N/A（632km）	φ9.7km
OCO-3	U.S.	-	394km	450kg	1	16km	~4km²
Microcarb	French	2020	650km	170kg	1	13.5km	2×2 km²
MERLIN	EU	2021		410kg	8ppb		φ100m
GEOCARB	U.S.	2022	35400km	138kg	>2.7	——	3×6km2

And more …

We are going to improve

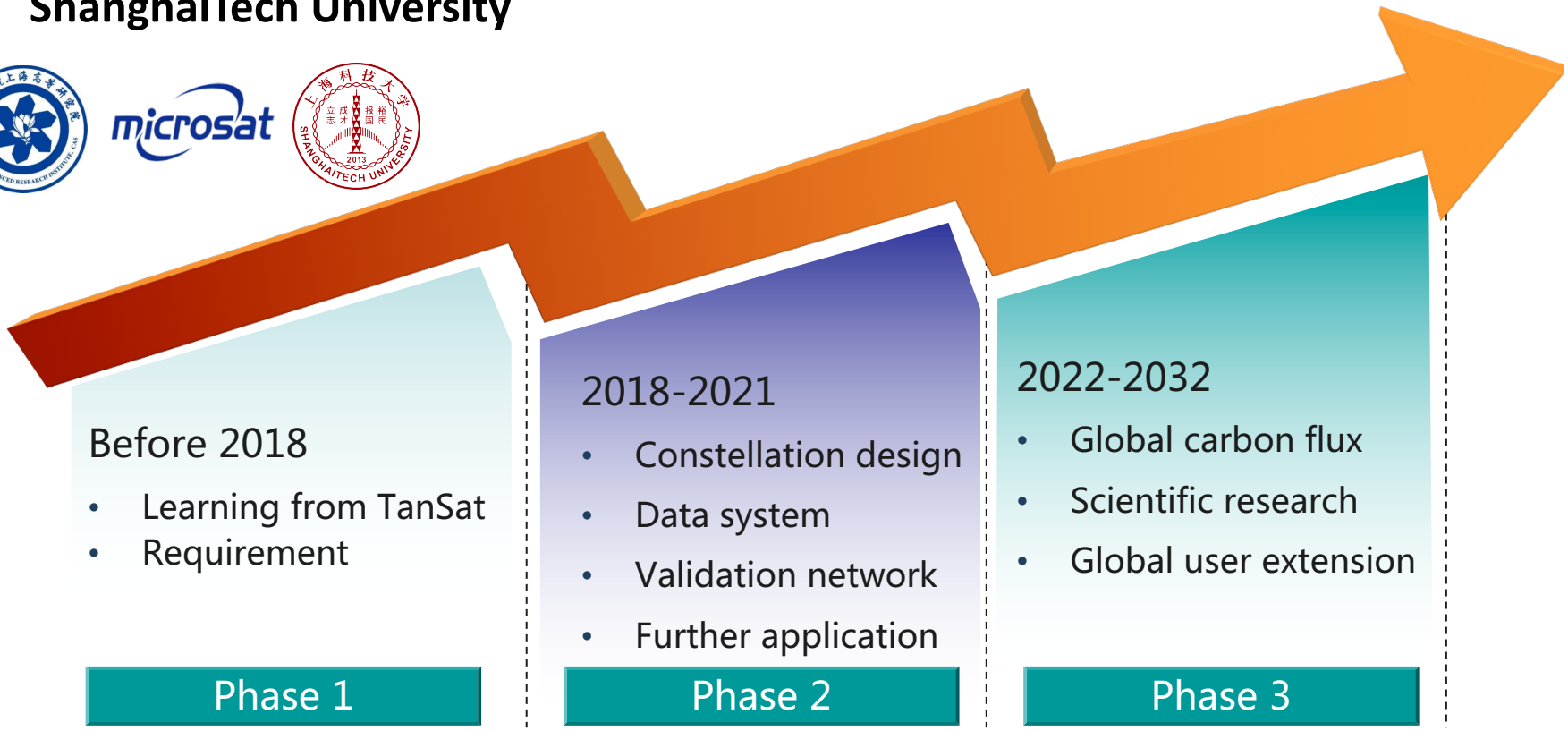
- **Target**
  - More gas species
  - Accurate and precision
- **Repeat and coverage**
  - Near global coverage
  - Fast repeat cycle
- **Footprint and spatial resolution**
  - Reduce cloud contamination
  - Investigate the hotspot
- **Cost and time**
  - Reduce the cost of development and build
  - constellation

Footprint	Clear-sky
100km^2	13%
3km^2	27%
4km2	23%
1km^2	**35%**

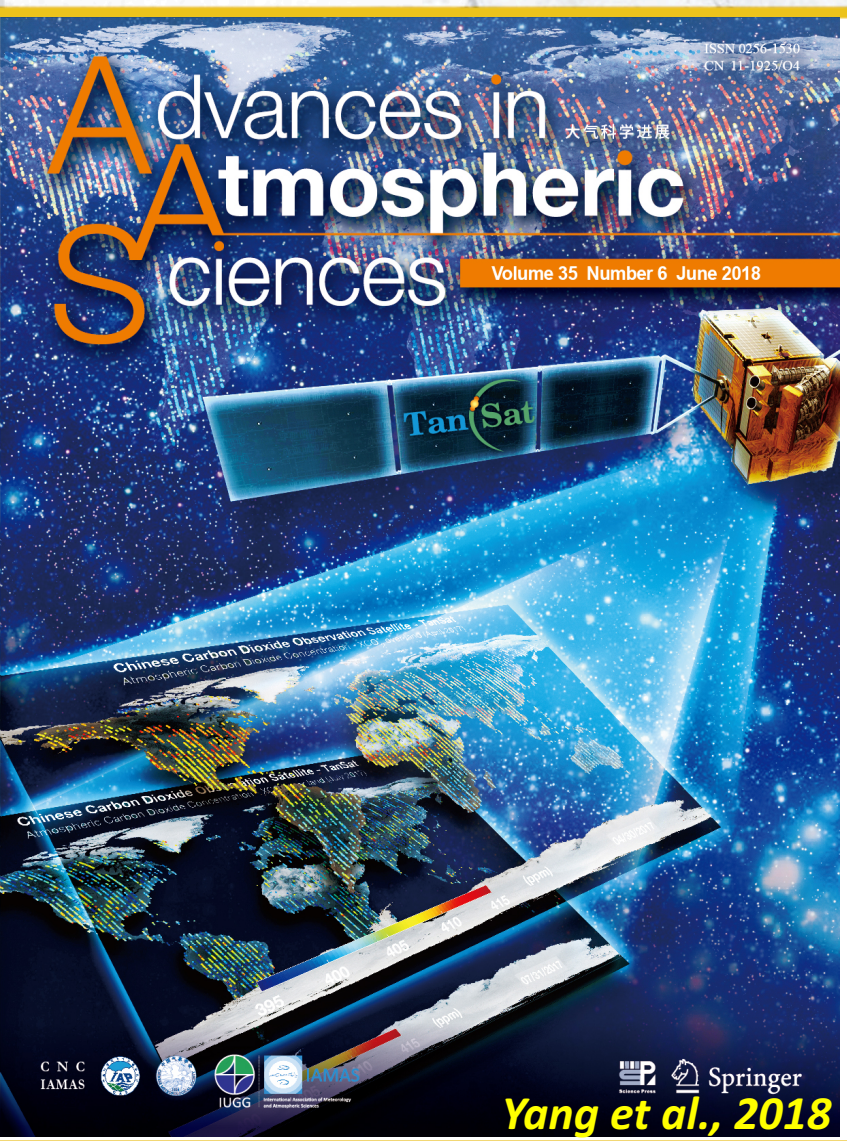
Mission overview

TanSat-2 mission is initiated by

- **Shanghai Advanced Research Institute, CAS**
- **Innovation Research Institute of Micro-Satellite, CAS**
- **ShanghaiTech University**



An extended monitoring platform for better understanding carbon budget and human emissions



Three instruments will onboard TanSat-2

For GHGs, pollution and aerosols

Instrument 1: GhGs

Specifications	TanSat	New constellation
Bands	• O_2-A • CO_2 Weak • CO_2 Strong	• O_2-A • CO_2 Weak • CO_2 Strong • CH4&CO
Bands/width/resolution（nm）	• 760/20/0.047 • 1610/30/0.12 • 2060/40/0.16	• 760/20/0.04 • 1610/30/0.08 • 2060/40/0.10 • 2300/50/0.11
SNR	360/250/180	350/300/200/200
Radiometric calibration	<5%	<4%
Footprint	2×2km	<2×2km
Swath	20km	>100km
Weight	220kg	<100kg
mode	Nadir/ glint /target/calibration	

Instrument 2: Pollutions

Gas	Bands
O3	Hartley: 260nm Huggins: 340nm Chappuis: 600 nm
NO2	220nm~400nm
SO2	350nm

	Specifications
Width	290nm~500nm
Resolution	<0.5nm
Footprint	2km×2km
Swath	>600km
SNR	>600
Weight	<30kg

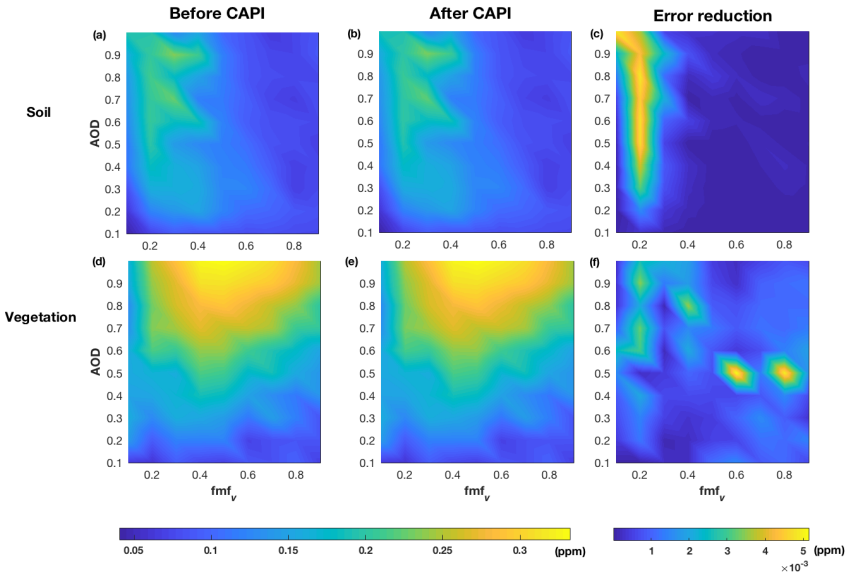
Detailed characteristics

Spectral ranges	Number of channels	Spectral resolution	SNR @ expected input radiance
270-495 nm	1200	0.55 nm	1000
710-775 nm	600	0.55 nm	500
2305-2385 nm	800	0.25 nm	100

- Design parameters:
  - spectral range: 320 – 495 nm
  - spectral resolution: 0.5 nm
  - spatial resolution: 0.1° (~1x1km^2)
  - field of view: 60° (full angle)

Instrument 3: CAPI2

	Specifications
Bands	0.38μm、0.67μm、0.87μm、1.375μm、1.64μm
Polarization	0.67μm、0.87μm、1.64μm 0°、60°、120°
Swath	>600km
Footprint	<0.5km
Radiometric calibration	<5%
Polarization calibration	<2%
SNR	>500
Weight	<30kg

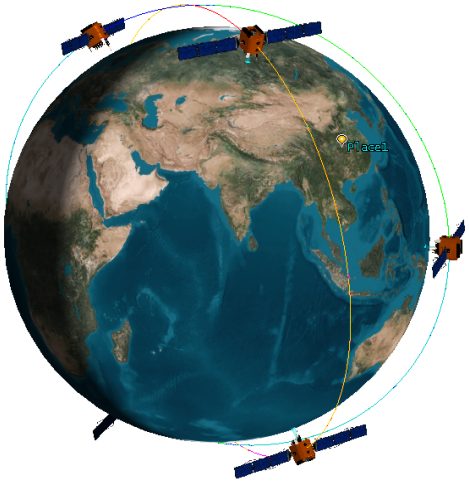


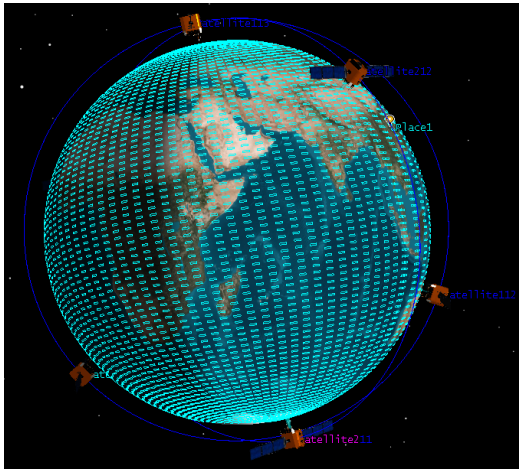
The Aerosol information content & Optimal aerosol model

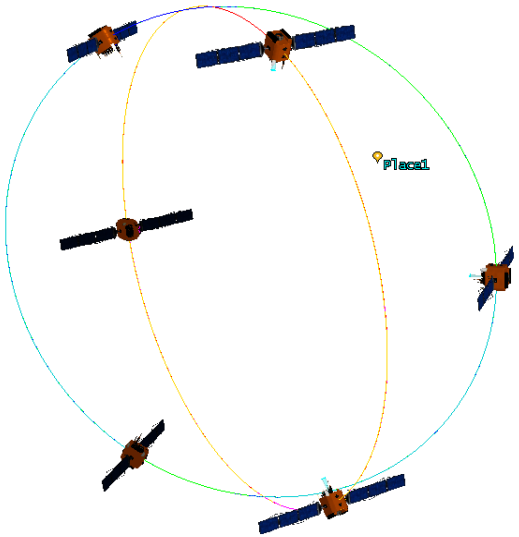
Liu et al., 2018, Chen et al., 2018

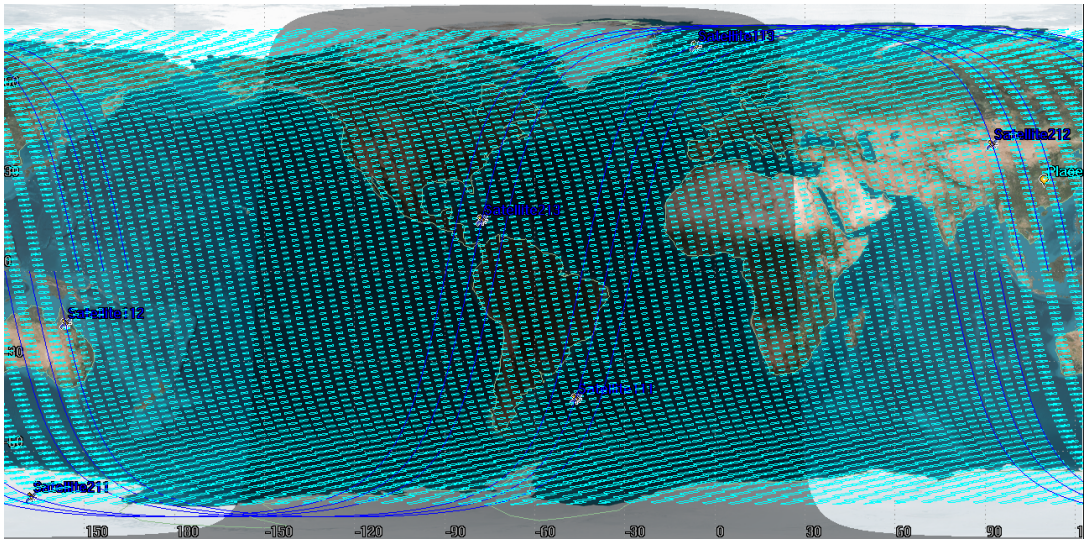
Flight orbit

- Two orbits, 2 or 3 Satellites each
  - Sun-synchronous orbit
  - 590 - 610 km
  - Morning 10:45
  - Afternoon 13:30



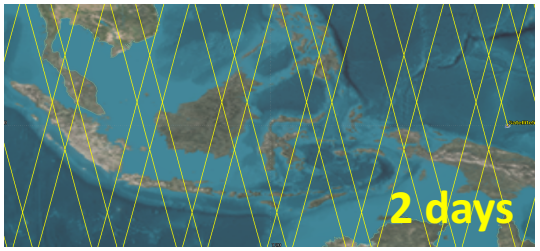


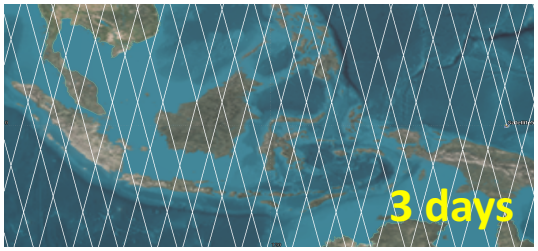


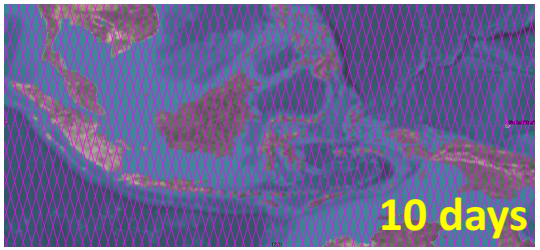


Orbit optimizing (3 satellites)

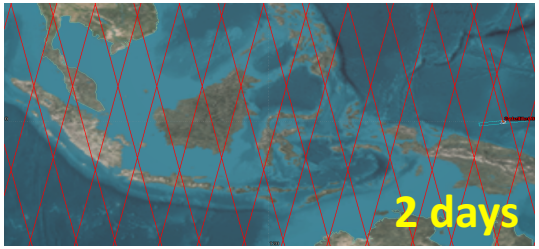
Repeat 10 days

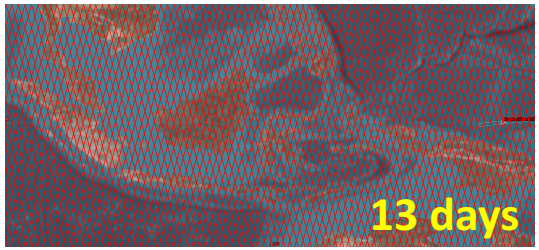




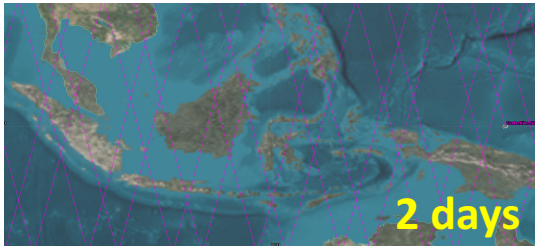


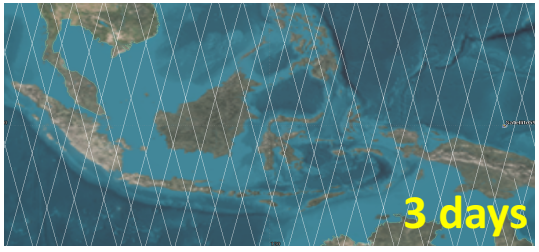
Repeat 13 days

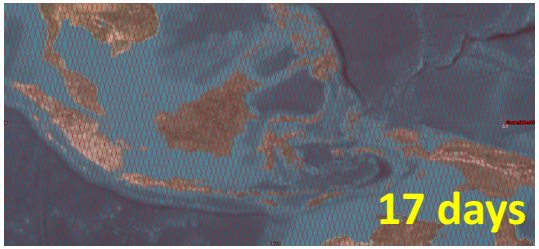


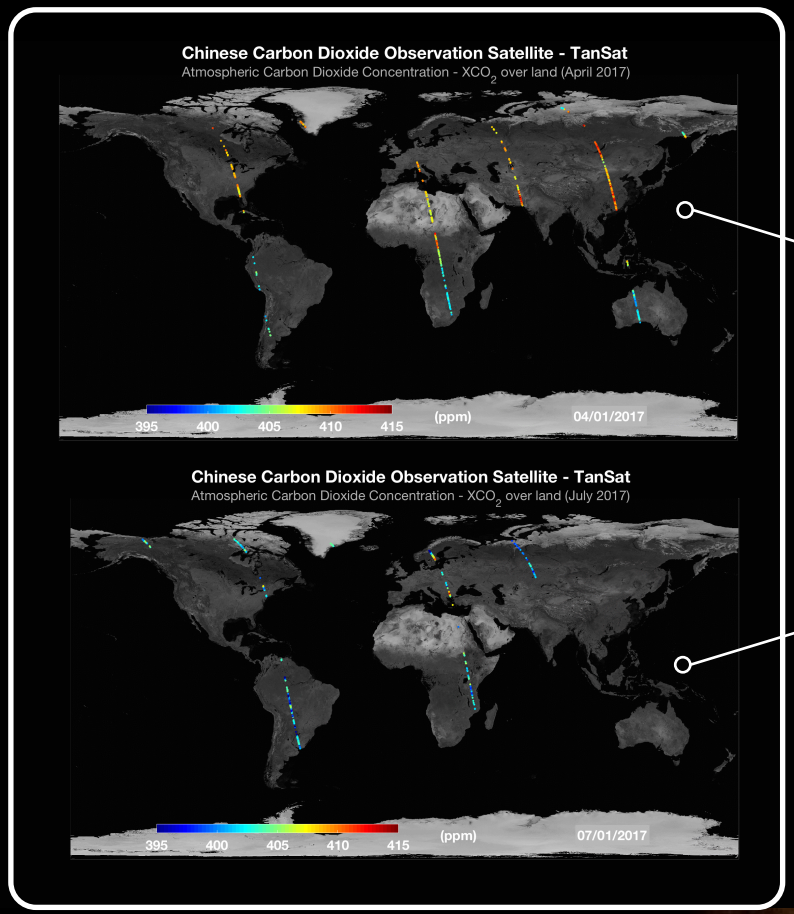


Repeat 17 days








Chinese Carbon Dioxide Observation Satellite - TanSat
Atmospheric Carbon Dioxide Concentration - XCO2 over land (April 2017)
395 400 405 410 415
(ppm)
04/01/2017
Chinese Carbon Dioxide Observation Satellite - TanSat
Atmospheric Carbon Dioxide Concentration - XCO2 over land (July 2017)
395 400 405 410 415
(ppm)
07/01/2017

Thank you!

Instrument 1: GhGs

Large-aperture Spatial Heterodyne Interference Spectrum (LASHIS)

A pair of parallel grating is introduced on the basis of LASIS. There is no slit in the system, which is equivalent to adding heterodyne lateral shearing interferometer in the common camera system. The detector acquires 2D images that superimpose the target interference information. The spectral information is restored by Fourier transform.