10th International Workshop on Greenhouse Gas Measurements from Space

Recent development in Chinese Carbon Dioxide Satellite (TanSat)

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Chinese Academy of Sciences

5-7 May 2014, ESA-ESTEC, Noordwijk, The Netherlands

Outline

1. Introduction of TanSat Mission
2. Satellite platform
3. Payload & Calibration
4. Ground based validation network
5. Retrieval algorithm
6. Current Status and Schedule

1. The TanSat Mission –Introduction

(1) National High Technology Research & Development Programs by Ministry of Science and Technology of China (MOST)

Term-1 (2011-2015)-SECM

Term-2 (2013-2015) – IAP

(2) Strategic Priority Research Program of the Chinese Academy of Sciences-Climate Change: Carbon Budget and Relevant Issue by Chinese Academy of Sciences (CAS) – (2011-2015) – IAP

Tagert

Term-1(2011-2015)

Measurement Goals

XCO2

1~4 ppmv

Monthly

500 x 500 km^2

Term-2(2013-2015)

Measurement Goals

CO2 Flux

Relative flux error

20%

Monthly

500 x 500 km^2

Team of The TanSat Project

Team Leader	Mission
Zengshan Yin **Shanghai Engineering Center for Microsatellites**	**Team leader and Satellite platform**
Yuquan Zheng **Changchun Institute of Optics, Fine Mechanics and Physics**	**Carbon Dioxide Spectrometer**
Changxiang Yan **Changchun Institute of Optics, Fine Mechanics and Physics**	**Cloud and Aerosol Polarization Imager (CAPI)**
Zhongdong Yang **National Satellite Meteorological Center, CMA**	**Data receiver, Calibration and Operational Process**
Yi Liu **Institute of Atmospheric Physics, CAS**	**Science requirement， CO2 Retrieval Algorithm, Validation and Application**
Xiangjun Tian **Institute of Atmospheric Physics, CAS**	**CO2 Flux inversion**
Chengcai Li **Bekjing University**	**Aerosol and cloud Retrieval Algorithm for CAPI**

2. Satellite Platform - Observation Mode

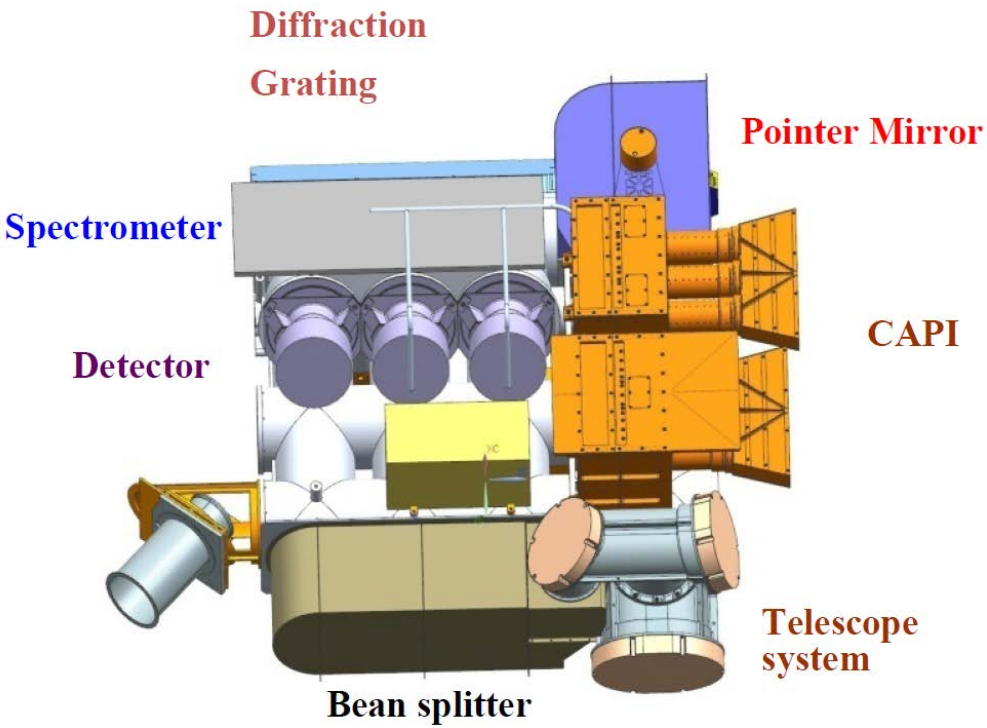
Name	Characters
Orbit type	sun-synchronous
Altitude	700 km
Inclination	98°
Local time	13:30 ±30min
Weight	500Kg

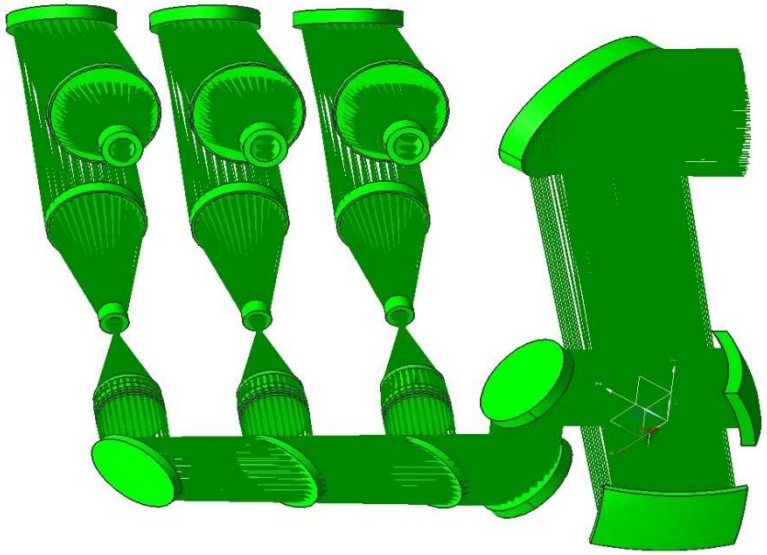
Nadir mode- Observation over land
- Push broom
- Principle plane track

Sun-glint mode- Observation over ocean
- Sun glint track
- Principle plane track

Target mode- Validation
- Surface target track
- Multi angles for one target

3. Carbon Dioxide Spectrometer





	O2-A	CO_2 weak	CO_2 Strong
Spectral Range (nm)	758-778	1594-1624	2042-2082
Spectral Resolution	0.044	0.12	0.16
SNR	360	250	180
Spatial Resolution	1km×2km, 2km×2km		
Swath	20km		

Cai Z. P59, Poster Session

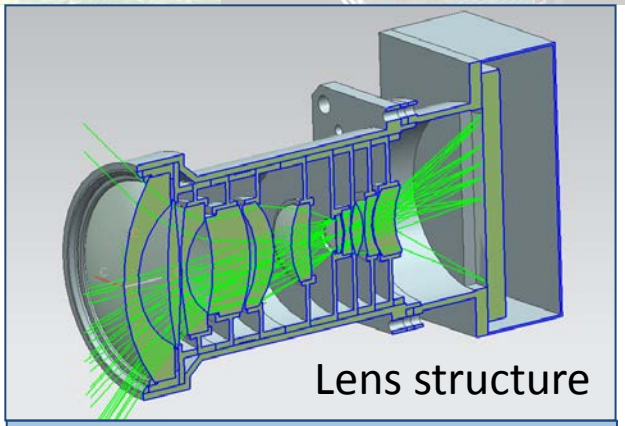
Cloud and Aerosol Polarization Imager - CAPI

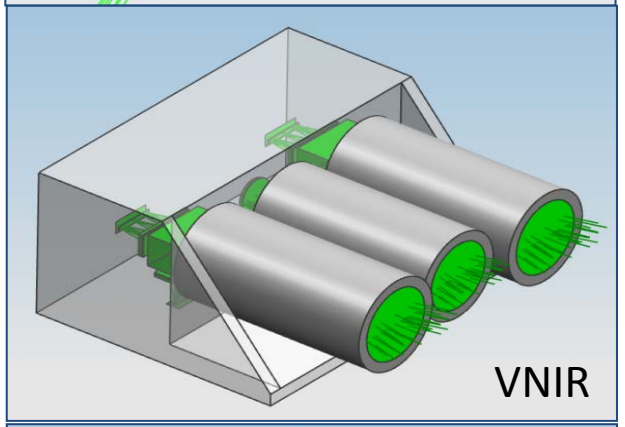
Instrument Specs of CAPI

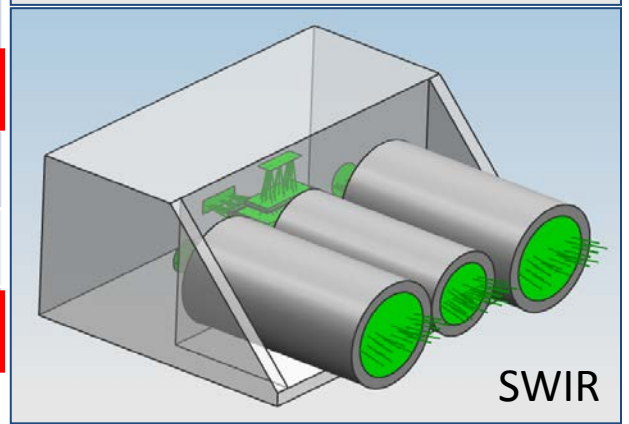
Name	Characters
FOV	400km
Spatial resolution	500m
VIS Samples	800
NIR Samples	800

Channel Specs of CAPI

λ [μm]	Range	SNR	polarization angle
0.38	0.365-0.408	260	-
0.67	0.66-0.685	160	0°, 60°, 120°
0.87	0.862-0.877	400	-
1.375	1.36-1.39	180	-
1.64	1.628-1.654	110	0°, 60°, 120°


Lens structure


VNIR


SWIR

Calibration

- Spectral Calibration accuracy:
  - superior to 1/10 FWHM
- Radiometric calibration accuracy:
  - 3%(relative)
  - 5%(absolute) (Also for CAPI)
- On Board Calibrator (OBC) :

  CO2 Spectrometer : LED + solar Calibration

  CAPI : LED +lunar + Solar Calibration

4. Validation measurement sites in China for Tan Sat

4 GGA

Greenhouse Gas Analyzer

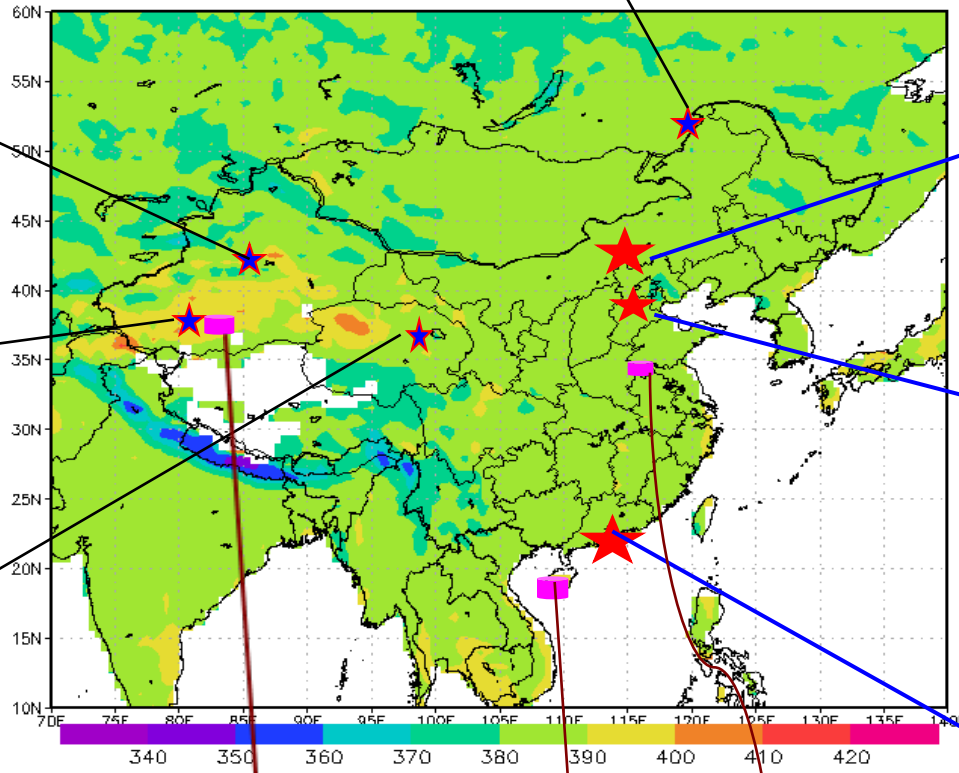
High-Lat site:

Mohe
(North-east of China)

3 IFS-125

West city site:
Urumqi
(West of China)

Xing Long
He Bei



Beijing
(East of China)

Background site:
Waliguan (GAW)

Low-Lat site:

Shenzhen
(South of China)

Map: SCIAMACHY XCO_2 2003-2009 in China

3 OSA

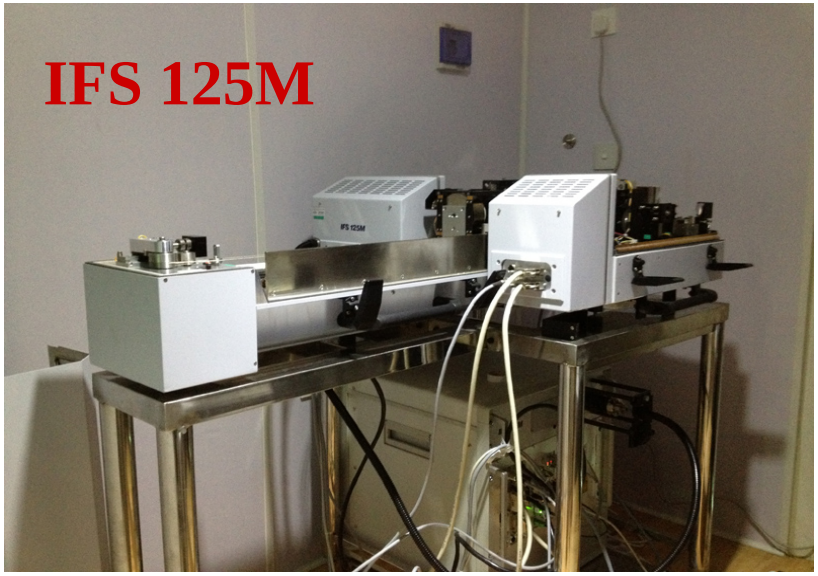
Optical Spectrum Analyzer

Taklimakan

Hainan Island

Shandong

Validation station with IFS125



Install in Xing Long, He Bei province June 2014

Validation station with OSA

2013. May-Aug in DongYing

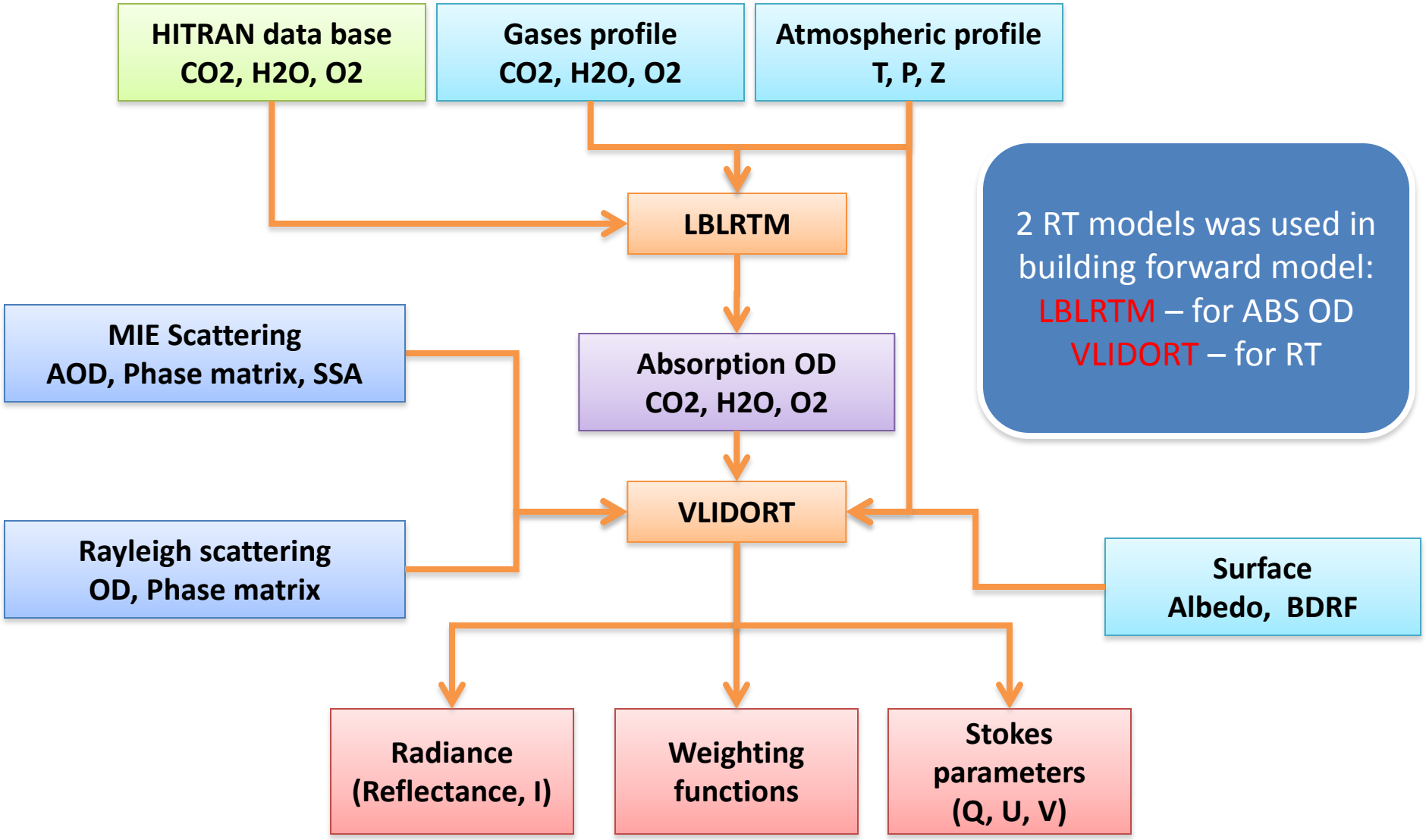
Moble Station

2013. Sep-Nov in DunHuang

Instruments in stations

- OSA for total column CO2 (Δλ=0.05nm)
- Aerosol optical parameters(POM-02)
- Grimm aerosol spectrometer
- Licor 7500, CAST3 for surace CO2
- P, T, Rh, Radiation(LW, SW)
- Whole Sky imager
- Sounding (CO2 and P, T, Rh, Wind)

5. Retrieval algorithm
Forward Model Framework



2 RT models was used in building forward model:
LBLRTM – for ABS OD
VLIDORT – for RT

The progress of TanSat XCO_2 algorithm

Aerosol model parameterization
- 2D wavenumber dependence
- Equivalence extinction

Cirrus cloud parameterization
- Retrieval effective radius
- Independent scattering and absorption

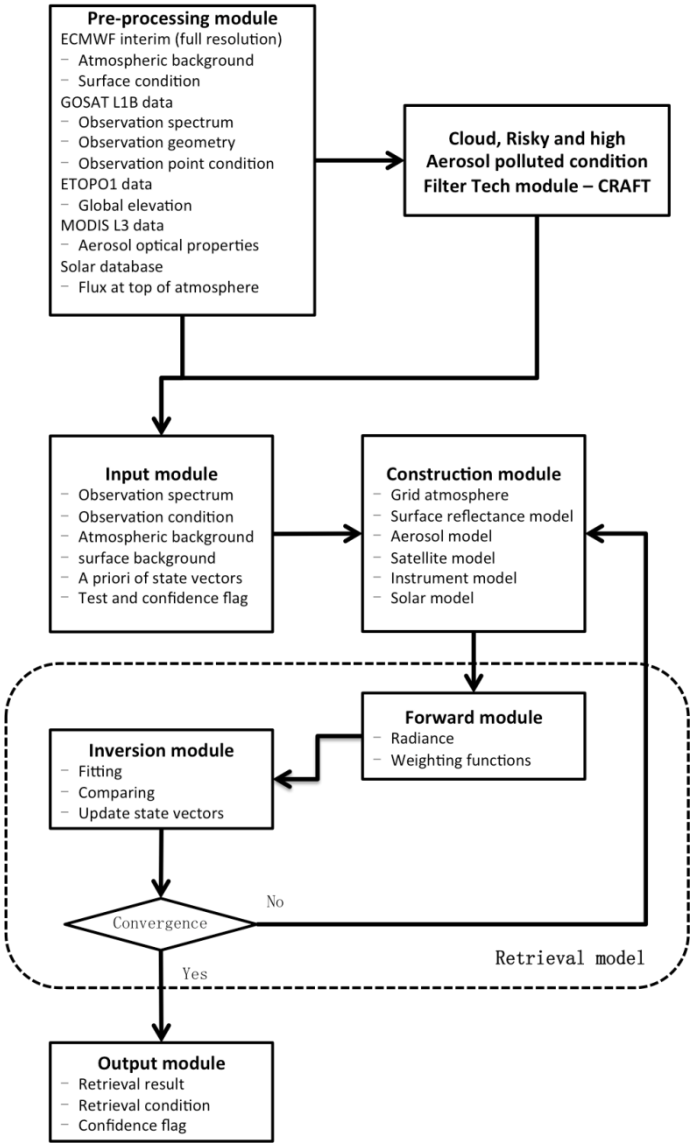
HITRAN 2012 -> ABSCO V4.2
- Air broadening
- Position
- Line profile
- Others

Shift correction on solar irradiance

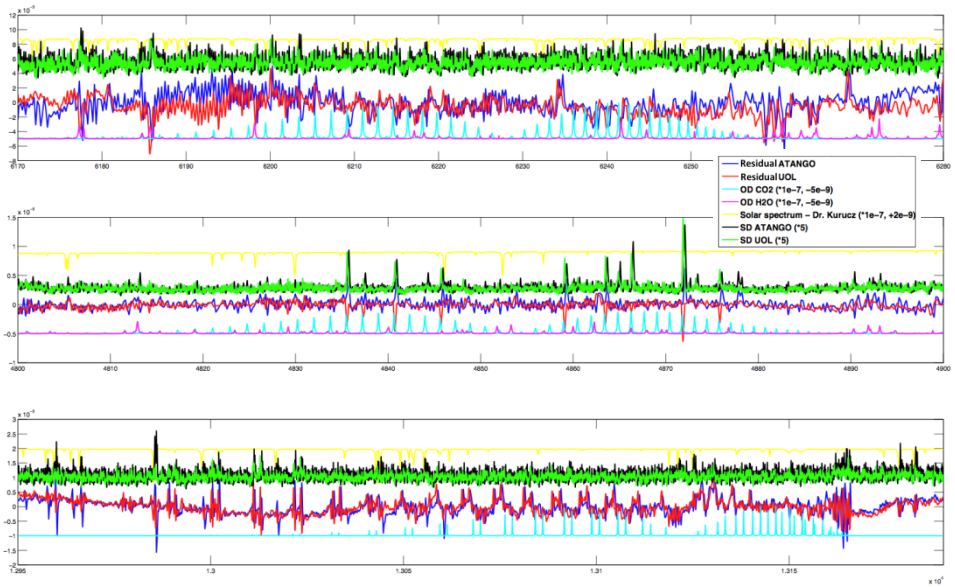
Zero offset for O2A band

Type	quantity	apriori	Explanation
CO2 profile	16	390 ppm	For each level
H2O scale	1	0	Profile scale factor
T shift	1	0	Temperature profile shift factor
Po	1	ECMWF	Surface pressure
AOD	1	0.1	Logarithm AOD at reference wavelength
H aerosol	1	2km	The altitude of aerosol layer center
Re aerosol	1	0.1um	The mode radius of scattering aerosol
Ratio	1	0.05	The OD ratio of absorption aerosol
COD	1	0.1	Cirrus cloud total column
H Ci	1	9.0km	Cirrus cloud altitude
Re scattering	1	20um	Scattering equivalent effective radius
Re absorption	1	20um	Absorption equivalent effective radius
albedo	6	Spectra	1 order fitting on each bands (2 factors)
WN shift	3	Spectra	Wavenumber shift on each band
Solar shift	3	0	Solar spectra wavenumber shift on each band
Zero offset	1	0	Radiance zero offset only for O2A band

Application of TanSat XCO_2 retrieval algorithm on GOSAT Observation – ATANGO

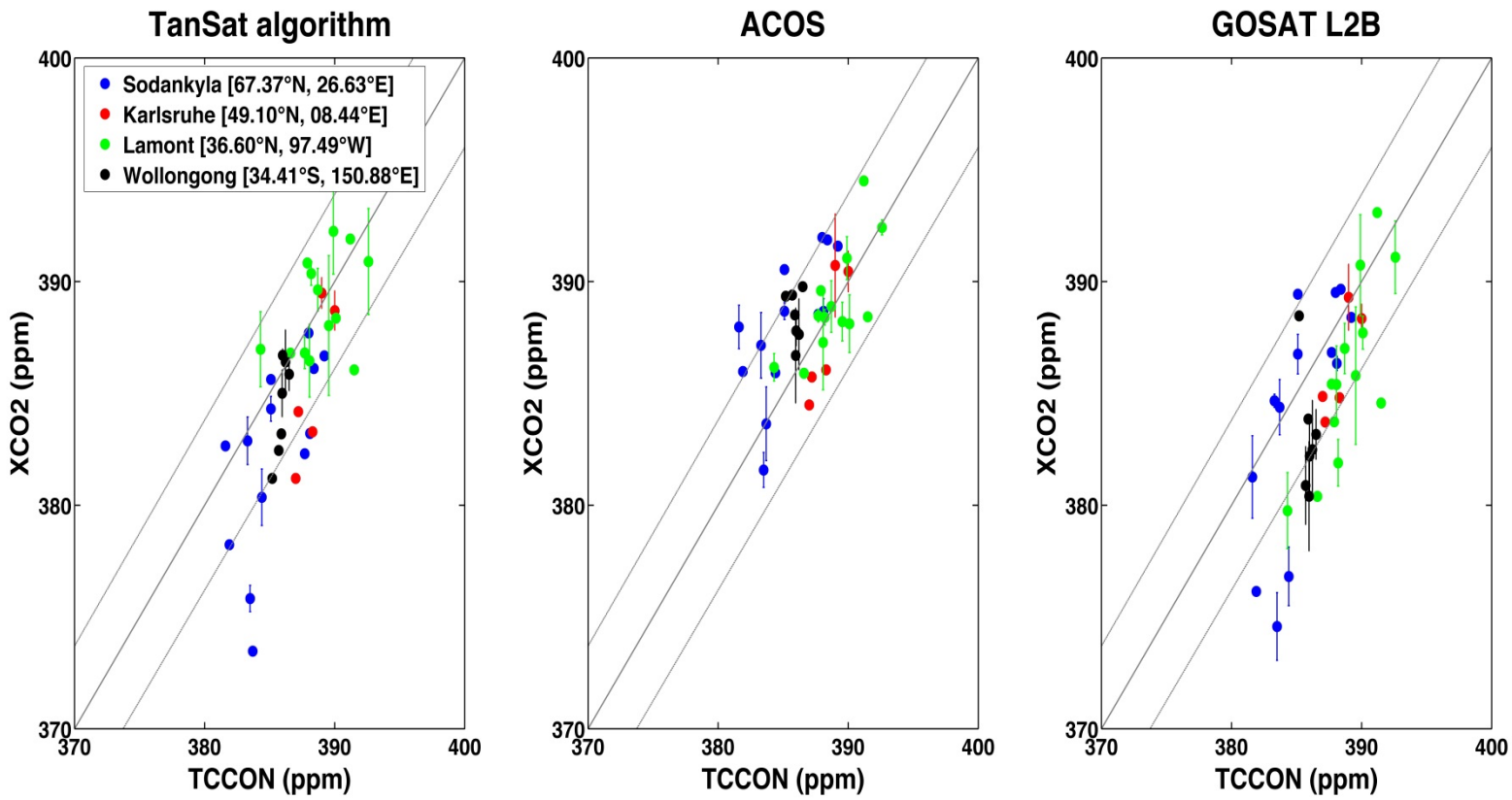


- Pre-processing module
- Cloud screening algorithm
- L1B pointing and degradation
- Output product
- Retrieval test



Yang D. P56, Poster session

Preliminary XCO_2 retrieval - Validation studies



Aerosol Retrieval with CAPI– a Test with MODIS Observations

STEP 1. Pre-processing

MOD02, MOD03, MOD35

PRE-PROCESSING:
- Cloud/Ocean screening
- Elevation correction
- Geometry determination
- Downscaling to $10\text{km} \times 10km$

INPUT:
- $R^*_{0.47}, R^*_{0.67}, R^*_{0.87}, R^*_{1.64}$
- Geometry Information

STEP 2. Retrieving

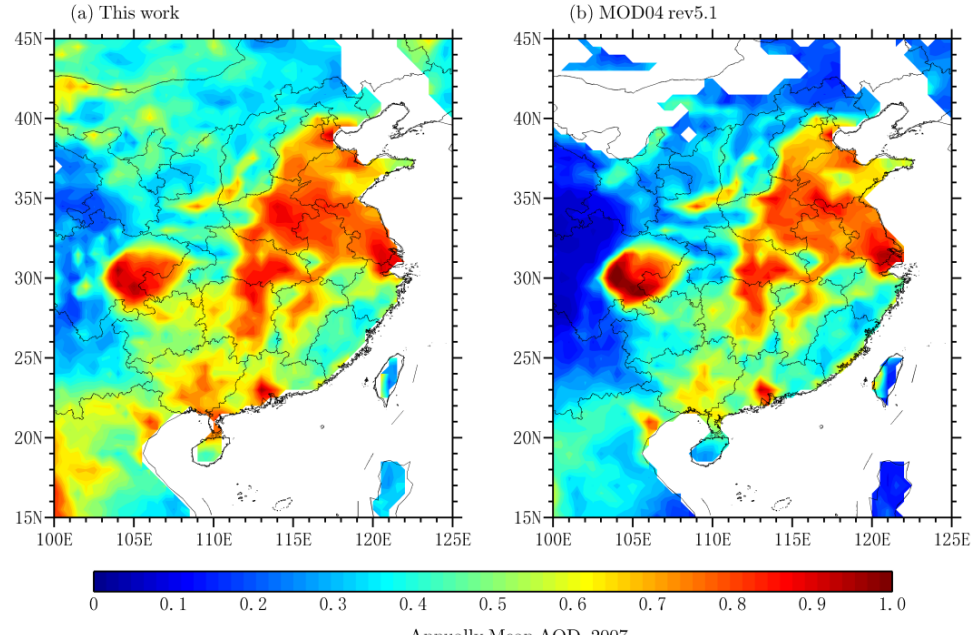
FOR EACH $\eta = -0.1, 0, 0.1, \ldots, 1.1$, FIND $\tau^{\eta}_{0.55}$, $R^{Surf,\eta}_{0.67}$, $sNDVI^{\eta}$, MAKES:
- $R^*_{0.67} = R^{LUT,\eta}_{0.67}$, $R^*_{0.87} = R^{LUT,\eta}_{0.87}$, $R^*_{1.64} = R^{LUT,\eta}_{1.64}$.

CALCULATE $\varepsilon^{\eta}_{0.47} = \left|R^*_{0.47} - R^{LUT,\eta}_{0.47}\right| / R^*_{0.47}$, FIND MINIMUM $\varepsilon^{\eta}_{0.47}$ TO DETERMINE η_0.

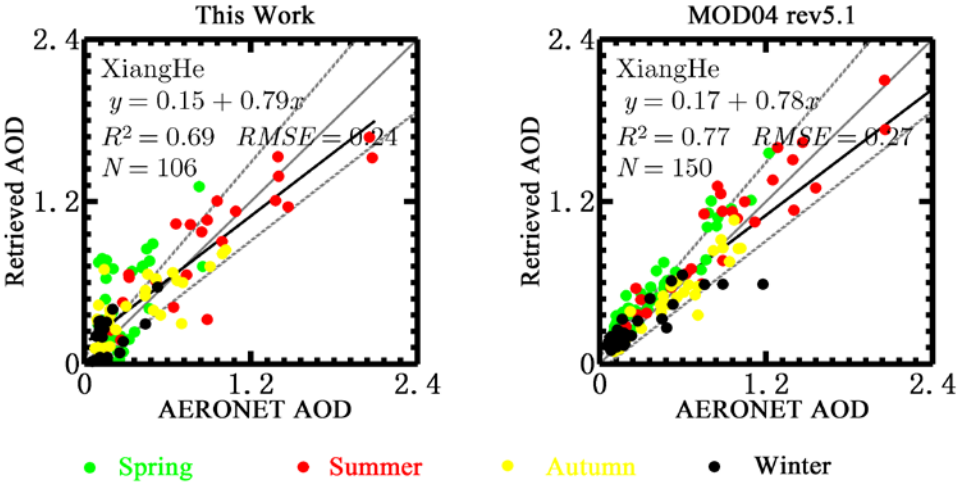
STEP 3. Outputting

OUTPUT:
- IF $\varepsilon^{\eta_0}_{0.47} < 0.05$, OUTPUT $\tau^{\eta_0}_{0.55}$, $R^{Surf,\eta_0}_{0.67}$, $sNDVI^{\eta_0}$, η_0.
- ELSE, RETRIEVE FAILED.

Algorithm Flowchart



Annually mean AOD in 2007



Comparing with AERONET AOD

G.M. Shi, C.C.Li et al., Retrieval of Atmospheric Aerosol and Surface Properties Over Land Using Satellite Observations, submitted to IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, 2014

Sensitivity Analysis of Polarization Reflectance

- Assume that the aerosol particles consist of a fine mode and a coarse mode

$$\frac{dVolume}{d\ln R} = constant \cdot \left\{ \frac{1}{SIGF} \cdot \exp\left[-\frac{(\ln R - \ln RF)^2}{2(SIGF)^2} \right] + r \cdot \frac{1}{SIGC} \cdot \exp\left[-\frac{(\ln R - \ln RC)^2}{2(SIGC)^2} \right] \right\}$$

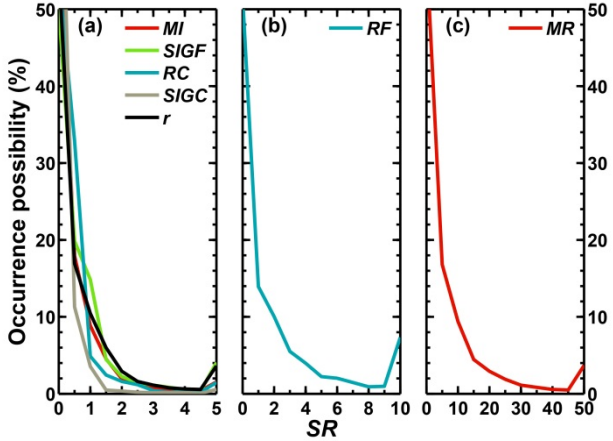
- Define the sensitivity ratio (SR) as the relative change of TOA polarization reflectance R_P due to the change of a single parameter X:

$$SR = \frac{\Delta R_P}{R_P} \Big/ \frac{\Delta X}{X}$$

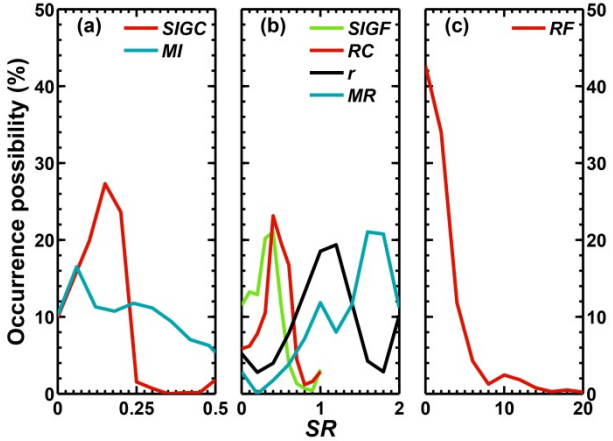
- Larger SR indicates that more precise X is necessary to get accurate simulating of R_P.

Parameters	Value Ranges
RF	0.05 - 0.25
SIGF	0.2 - 1.0
RC	2.0 - 6.0
SIGC	0.5 - 2.5
r	0 - 4.0
MR	1.35 - 1.65
MI	0 - 0.08

Value ranges of aerosol parameters



Occurrence possibility of SR at 0.66 μm

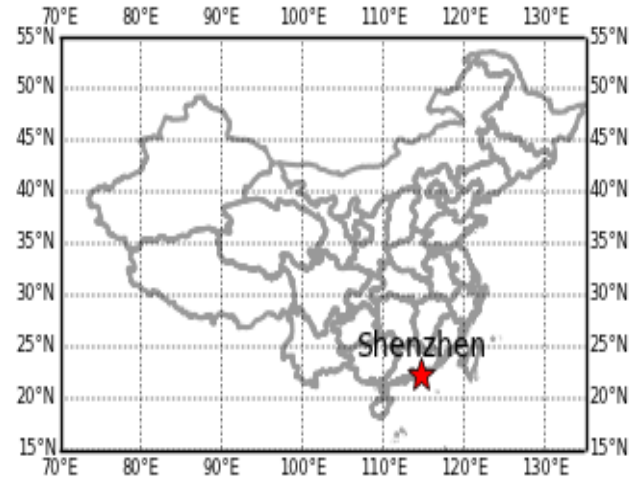


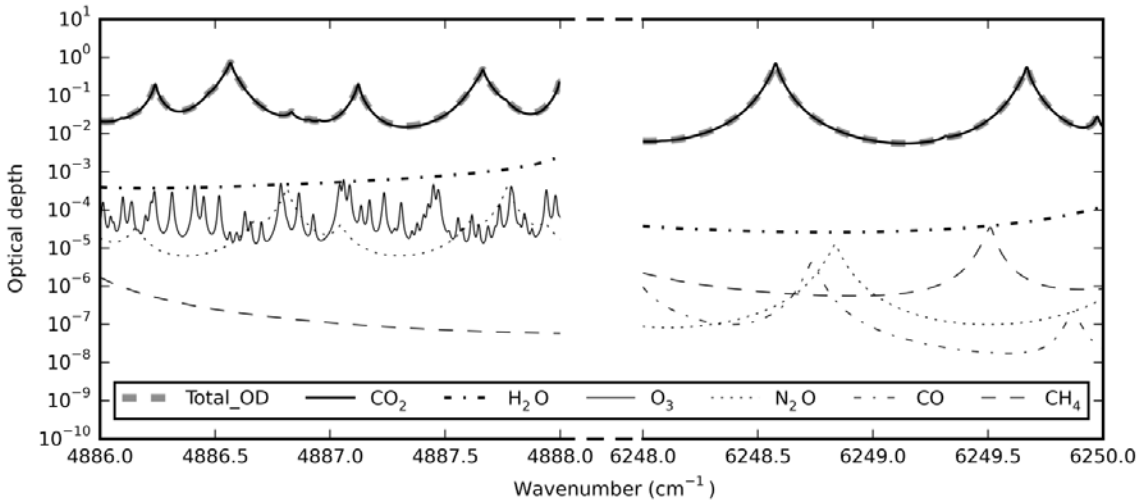
Occurrence possibility of SR at 1.64 μm

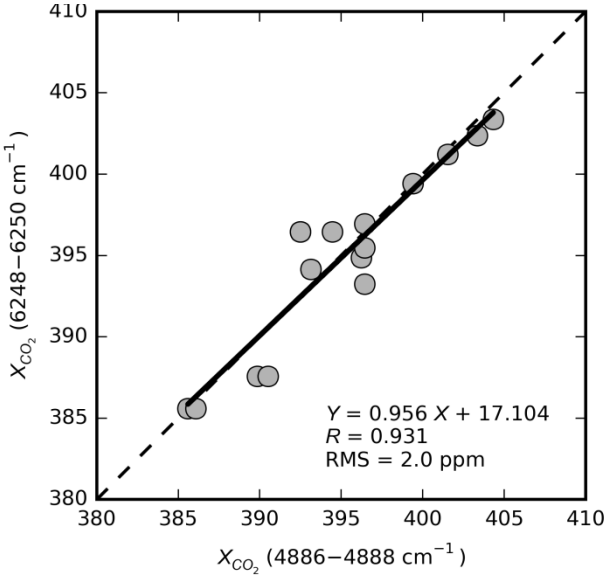
- **The most possible retrieval targets are MR, RF, and r as to their impact on R_P.**

Guangming Shi, Chengcai Li, Tong Ren, 2014: Sensitivity analysis of single-angle polarization reflectance observed by satellite. Chin. Sci. Bull. DOI 10.1007/s11434-014-0213-x.

Retrieval of XCO2 with ground-based Fourier Transform Spectrometer (IFS-125) in Shenzhen, China







--Measured at Xichong (22˚29'N,114˚33'E), in Shenzhen

--38 observations from 16 days (Sep.2011 to Feb.2012)

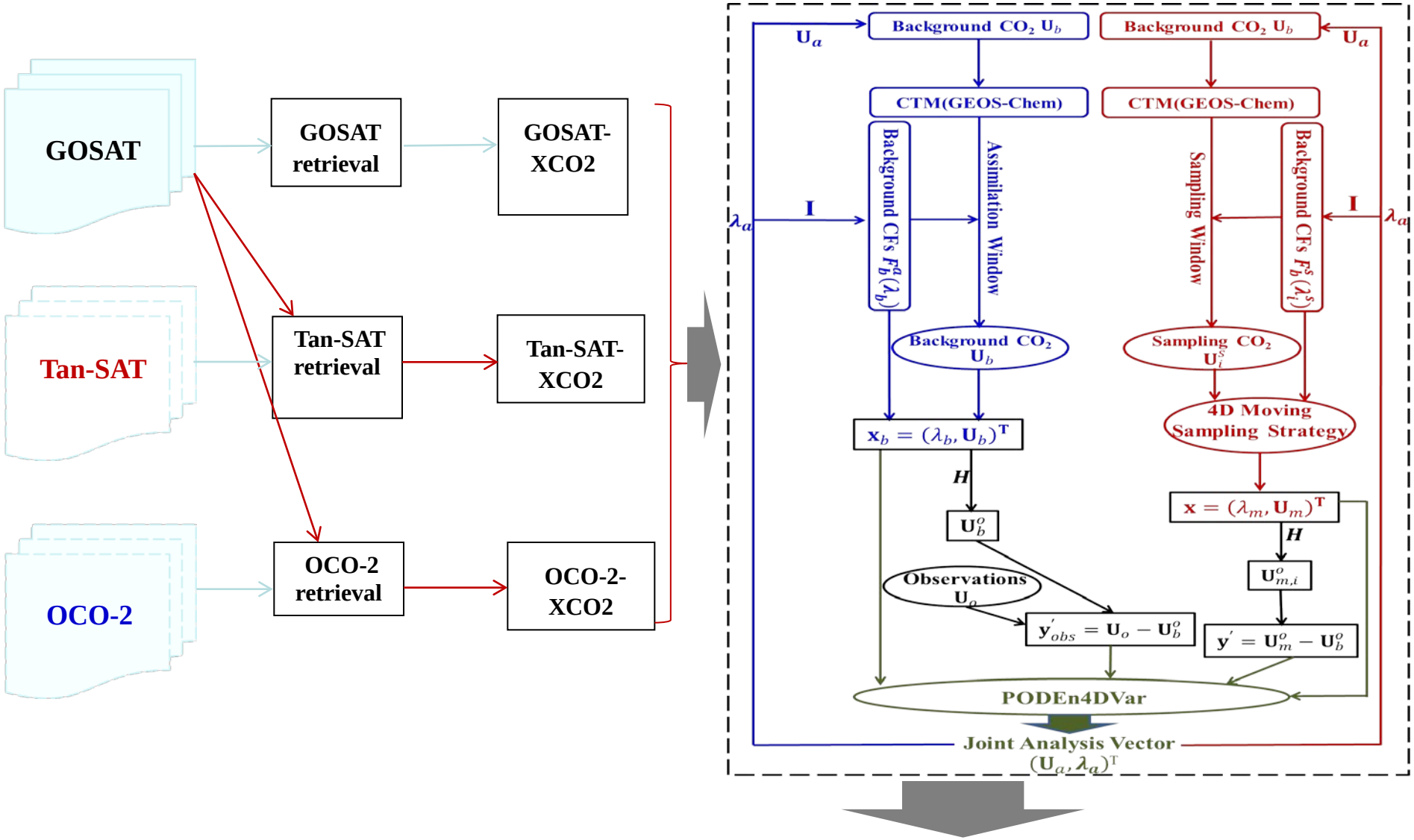
--Based on the theory of DOAS

--Retrieved at two bands separately

--Average of XCO2 was about 394.9 ppm

Jian Li, Chengcai Li, Jietai Mao, Dongwei Yang, Dong Wang, Lin Mei, Guangming Shi, Yefang Wang, Xia Mao, 2014: Retrieval of column-averaged volume mixing ratio of CO2 with ground-based high spectral resolution solar absorption. Chin. Sci. Bull. DOI 10.1007/s11434-014-0261-2.

CO_2 Flux—inversion model---→ Tan-Tracker



Simultaneously Estimate Surface CO_2 fluxes and 3-D Atmospheric CO_2 Concentrations

Tian et.al, Atmos. Chem. Phys. Discuss, 2013

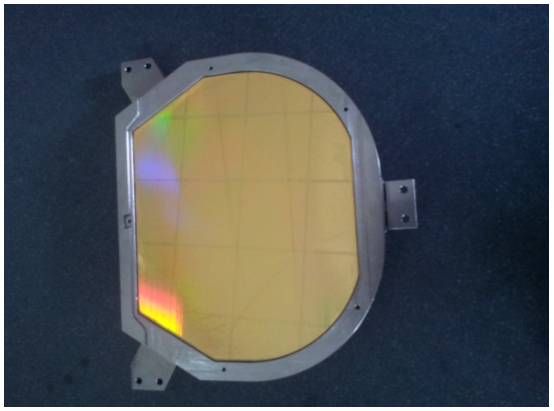
Special Issue on *Chinese Science Bulletin* (2014) 59(14)

Author	Title
Yi Liu	Effects of spectral sampling rate and range of CO2 absorption bands on XCO2 retrieval from TanSat hyperspectral spectrometer
Hailei Liu	Algorithm for Retrieving Surface Pressure from Hyper-spectral Measurements in Oxygen A-Band
Guangming Shi	Sensitivity Analysis of Single-Angle Polarization Reflectance Observed by Satellite
Xiangjun Tian	Chinese Carbon Cycle Data Assimilation System (Tan-Tracker)
Jianbo Deng	CH4 retrieval from hyperspectral satellite measurements in short-wave infrared: Sensitivity study and preliminary test with GOSAT data
Ying Zhang	Methane Retrieval from Atmospheric Infrared Sounder using EOF–based Regression Algorithm
Chengcai Li	Retrieval of column-averaged volume mixing ratio of CO2 with ground-based high spectral sesolution solar absorption
Yinan Wang	Observed and simulated features of the CO2 diurnal cycle in the boundary layer at Beijing and Hefei, China
Li Zhang	China's sizeable and uncertain carbon sink: A perspective from GOSAT

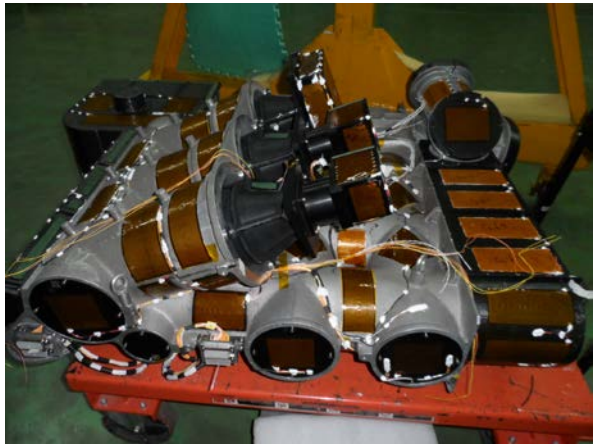
6. Current Status

- **Three prototype spectrometers are developed (760, 1610, 2060nm)**
- **Large-area diffraction grating is manufactured, but face challenge in improving diffraction efficiency and wave front.**
- **Prototype model and electrical interface test has been finished!**
- **CAPI is on the schedule**

760nm Prototype



Large-area grating



Electrical and thermal experiment

Mechanical experiment

TanSat Schedule

2011.02 kick off of project

2011.09 SRR-Science Requirement Review

2013.03 PDR-Preliminary Design Review

2013.06: Kick off phase C

Technical challenge – build Large-area grating

2014.06: Electromechanical Integration

2014.12 CDR- Critical Design Review—major milestone

Assemble, debug, integrate, a series of test: calibration\environment

2015.12 SRR- Satellite Readiness Review

2016.06 Launching


Thank You!