Institute of Remote Sensing and Digital Earth
Chinese Academy of Sciences

Hefei Institutes of Physical Science
Chinese Academy of Sciences

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GaoFen-5 GHG Monitoring Instrument

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Outline

- GaoFen-5 mission
  - ✓Overview
  - ✓Payloads onboard
- GHG Retrieval Method
  - ✓Aerosol Scattering
  - ✓Cloud detect
  - ✓Optimal Estimate

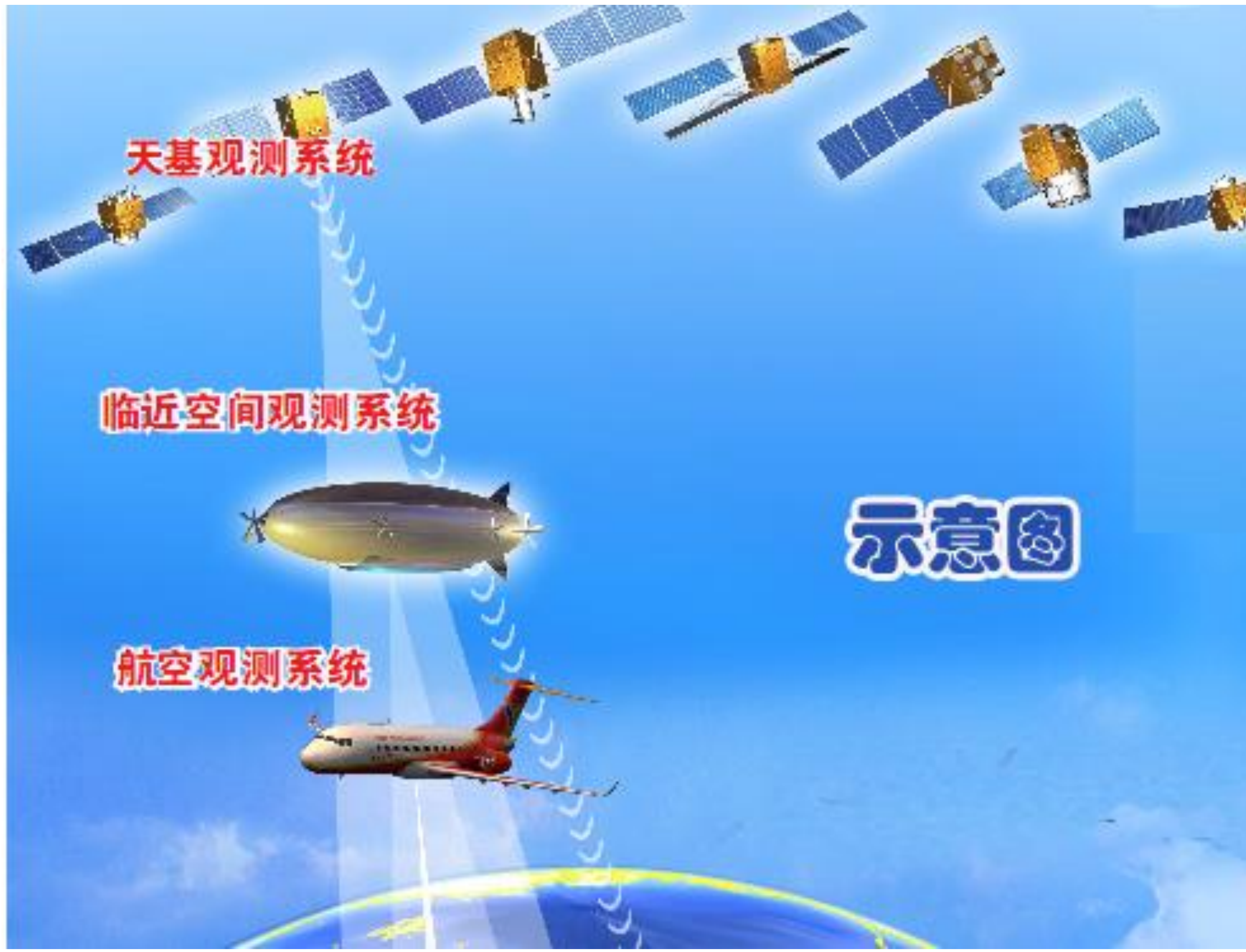
Part1:GaoFen Mission

High-resolution earth observing system, an important component of China sustainable development plan of science and technology from 2006 to 2020.

Space-based

High-altitude

Flight



Space-based: GaoFen series

GaoFen-1

Launch: 2013.4；

Polar Orbit；

Resolution: 8m/2m

Bandpass:0.45~0.89

Swath: 60km

Revisit: 4days

GaoFen-2

Launch: 2014.8；

Polar Orbit；

Resolution: 4m/2m

Bandpass:0.45~0.89

Swath: 45km

Revisit: 5days

GaoFen-3

Launch: 2016.8；

Polar Orbit；

Synthetic Aperture Radar (SAR);

Spatial resolution: 1m

C Band: 4~6GHz

GaoFen-4

Launch: 2015.12；

Geostationary Orbit；

Spatial resolution:

- VIS-NIR: 50m
- MNIR: 400m

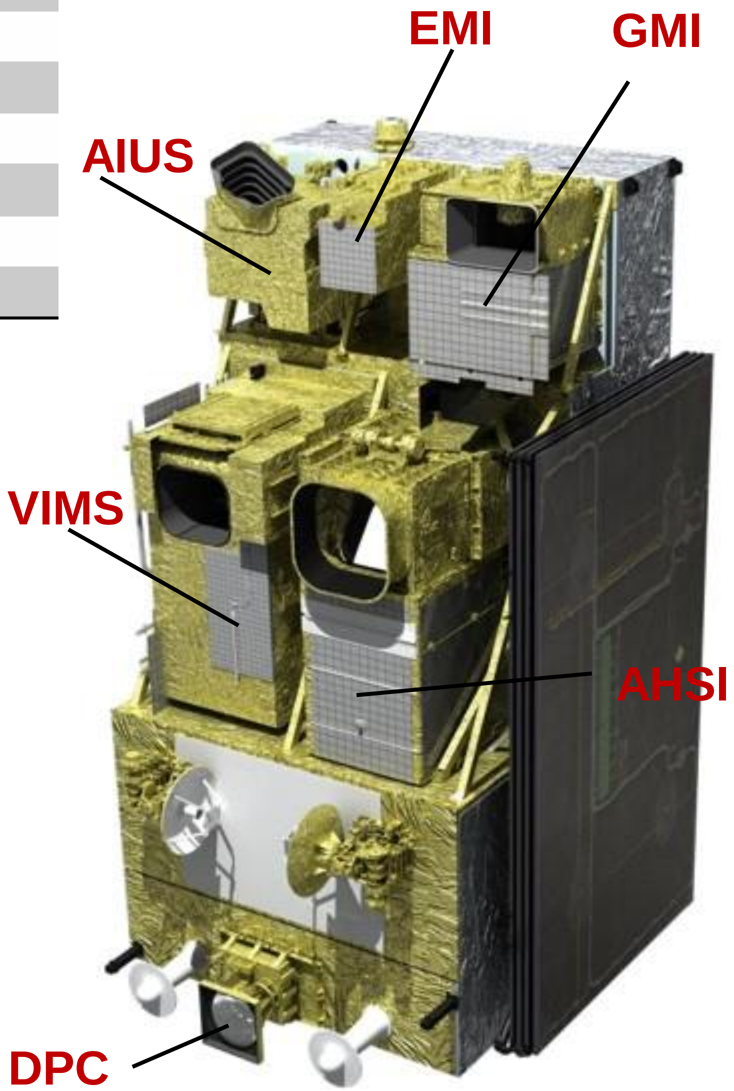
Swath: 400km

Sample interval: 20s

GaoFen-5 to be launched in early May

Orbital Type	Sun synchronous orbit
Nominal orbital altitude	708.45km
Dip angle	98.218
Orbital flat period	98.805min
Eccentricity ratio	E<0.0001
Flight cylinder number every day	14.57
Orbital intercept	24.731
Local time of descending node	1:30 pm

Sensors onboard GaoFen-5	Similar to
Greenhouse gas Monitoring Instrument (**GMI**)	GOSAT
Directional Polarization Camera (**DPC**)	Polder/Parasol
Environment Monitoring Instrument (**EMI**)	OMI
Atmospheric Infrared Ultraspectral (**AIUS**), FTS	ACE-FTS
Visual and Infrared Multispectral Sensor (VIMS)	——
Advanced Hyperspectral Imager (AHSI)	——

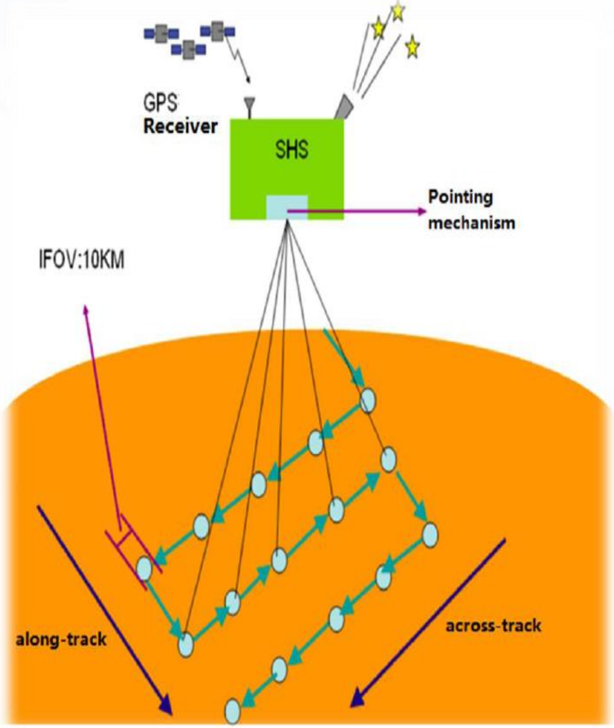


GMI: main parameters

	technical parameters			
	O_2	CO_2	CH_4	CO_2
Central wavelength(um)	0.765	1.575	1.65	2.05
Band width(um)	0.759-0.769	1.568-1583	1.642-1.658	2.043-2.058
Spectral resolution	0.6cm^{-1}	0.27cm^{-1}		
SNR	300@ =30%		250@ =30%	
Radiation calibration	5% (relative, ~2%)			
Size	790mm (X) ×690mm (Y) ×575mm (Z)			
Field of view	14.6mrad IFOV<10.3km@708km			
Sample	5、7、9-pints			
Observation mode	nadir(mainly)/glint			
Weight	109kg			
Power	120W			
Data transfer rate	30Mpbs			

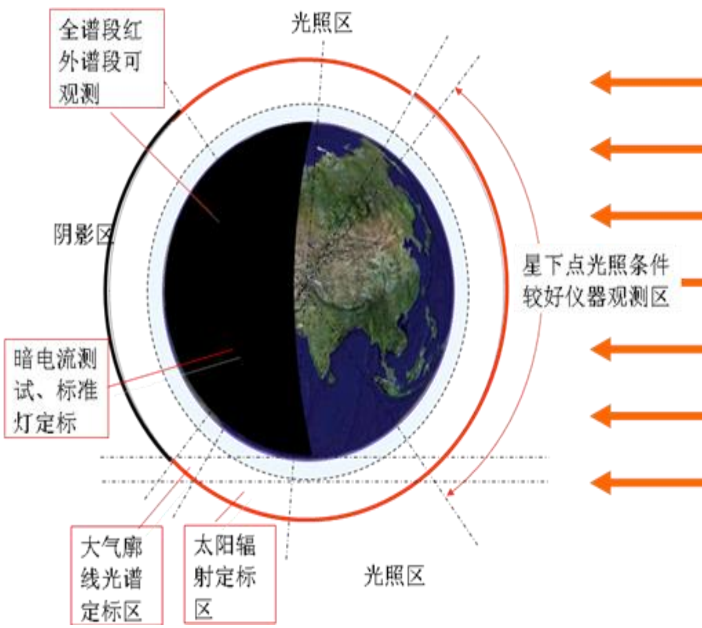
GMI observing strategy

Nadir model



Glint model

Calibration



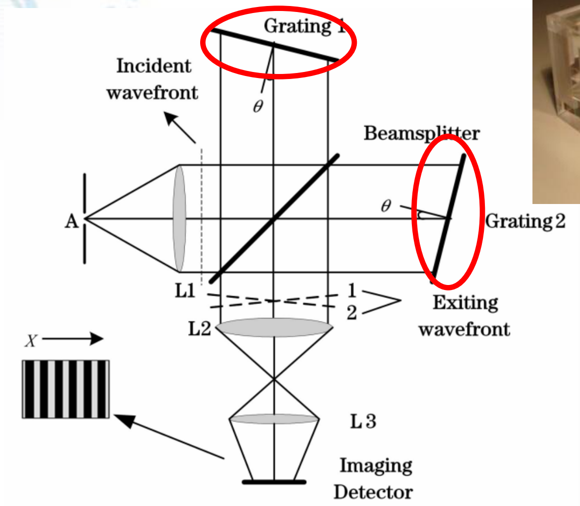
Observation patterns	Along track direction km)	Across-track direction (km)
5	100	212
7	130	142
9	130	106

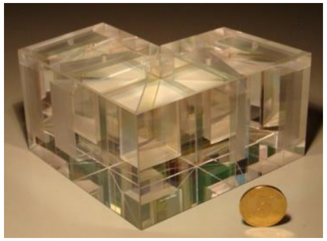
- Dark target
  - Light Trap
- Bright target
  - Solar irradiance

GMI data acquire and process

SHS：Spatial heterodyne spectroscopy.

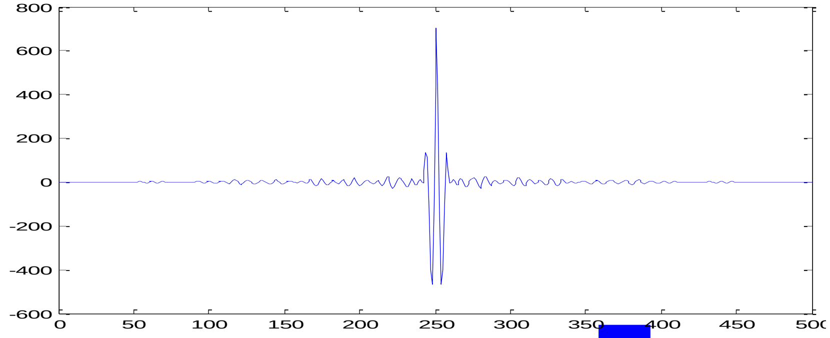
(J.Harlander., et.al, 1992)



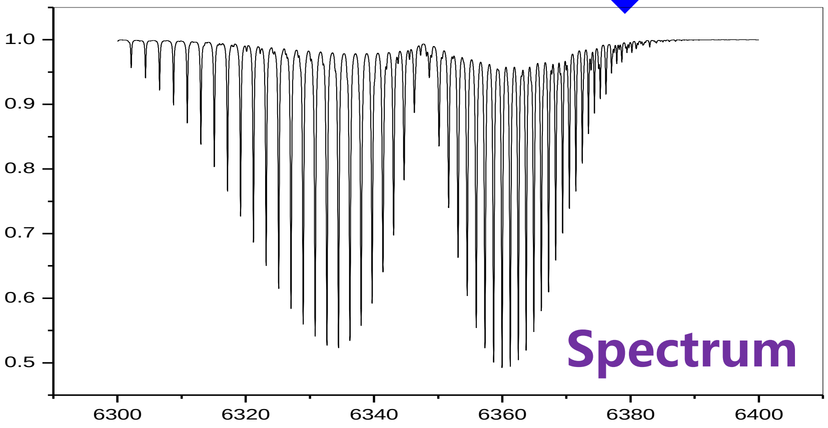


Sampling

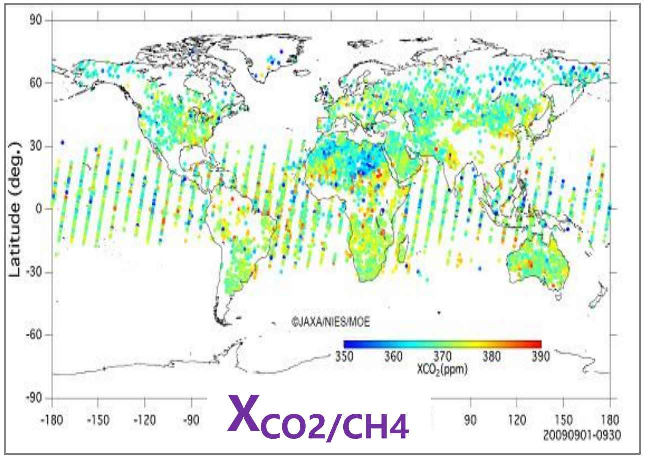
Interferogram



Fourier Transform



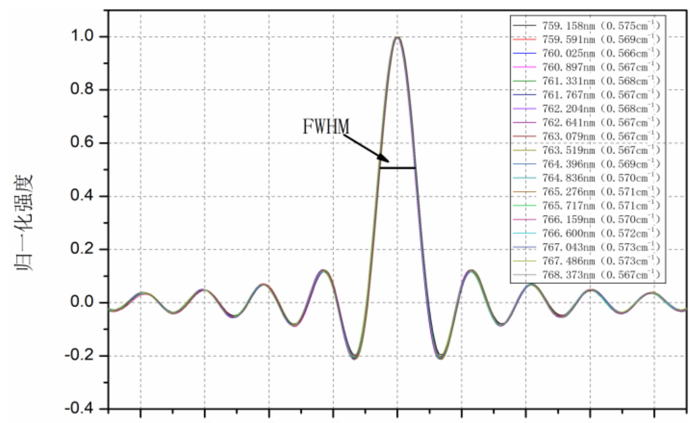
Retrieve



GMI: ground calibration

◆ Spectral calibration

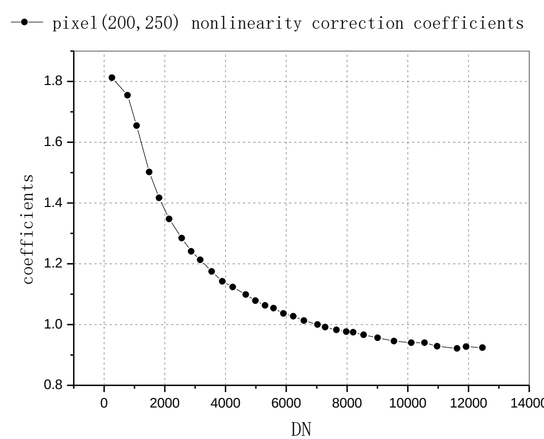
Spectral resolution test

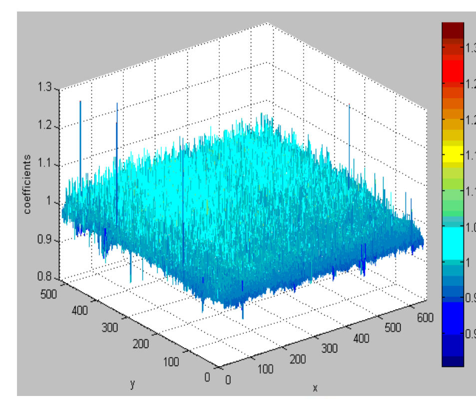


Full Width at Half Maximum

◆ Radiance calibration

correction of nonlinearity and inhomogeneity





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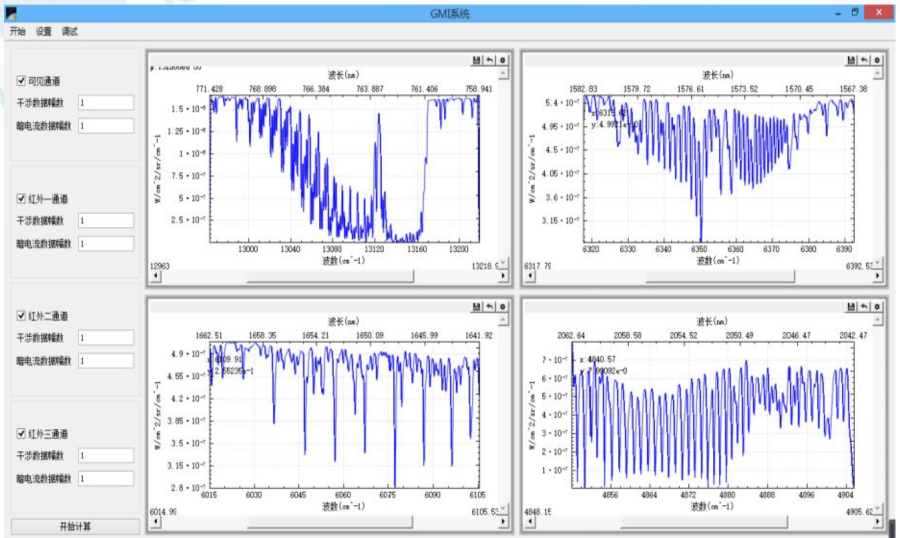
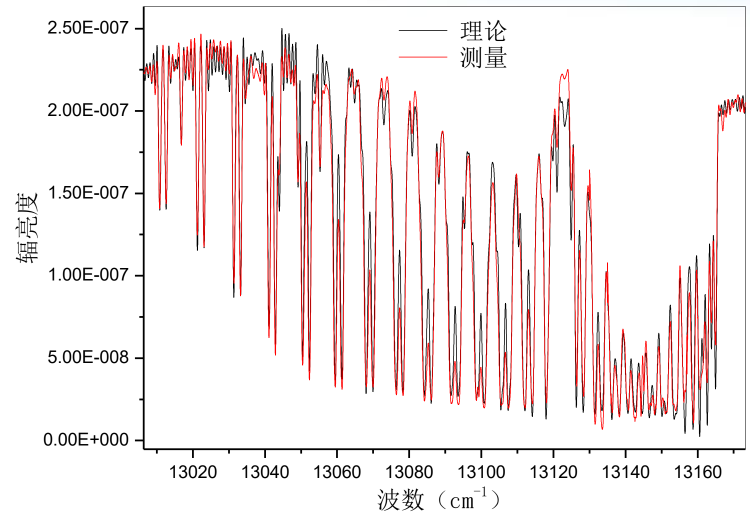
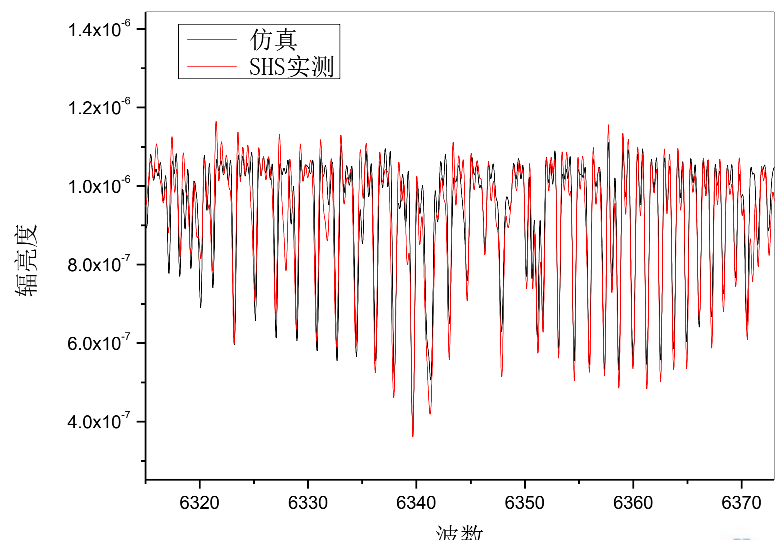
GMI: simulation and ground test







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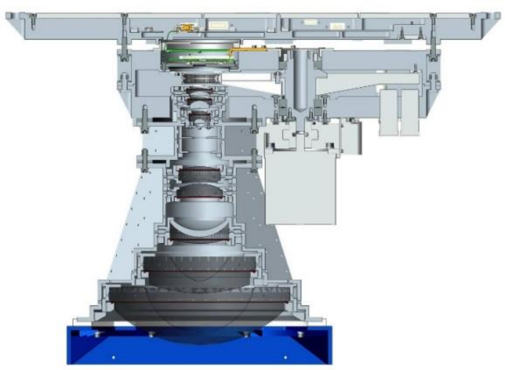
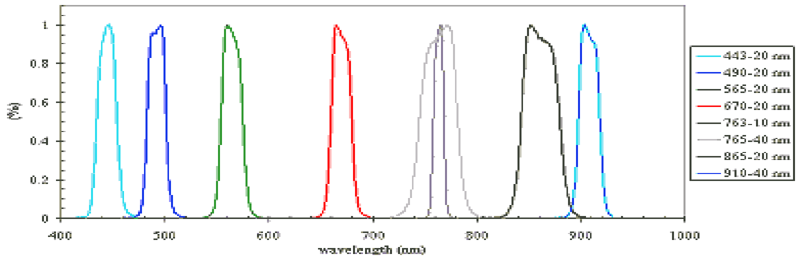
DPC: main parameters

Parameters	Specifications
Channel	433nm~453nm、 480nm~500nm（P） 555nm~575nm、 660nm~680nm（P） 758nm~768nm、 745nm~785nm 845nm~885nm（P）、900nm~920nm
SNR	Better than 500(Land)
Polarization Analysis	Linear polarization，Three directions:0°、60°、120°
FOV	−50° ～+50°
Multi-angular Measurements	9 angles along track
Spatial Resolution	**Better than 3.5 km(at nadir)**
Calibration	Better than 5%
Polarization Calibration	Better than 2%
Digitalizing Bit	12bits
Bit Rate	9.45Mbps

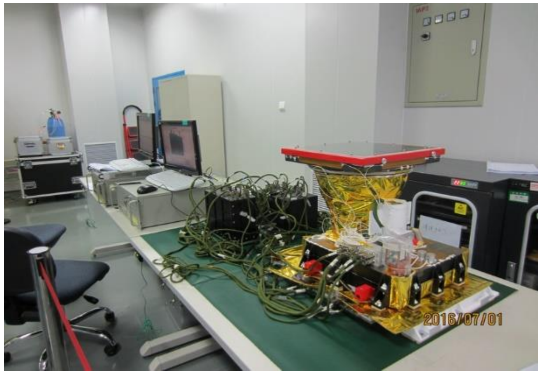
DPC design



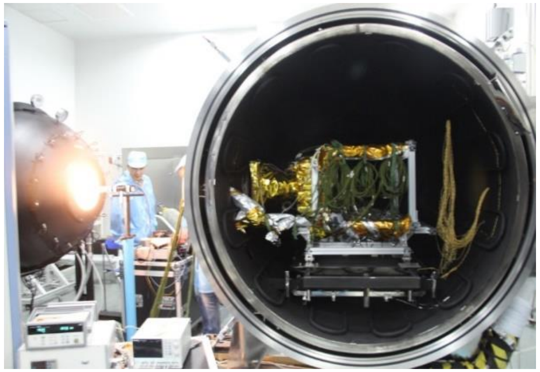


Mechanical part

Lens

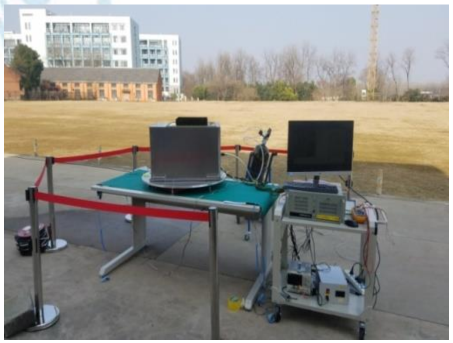


Testing of electrical interface

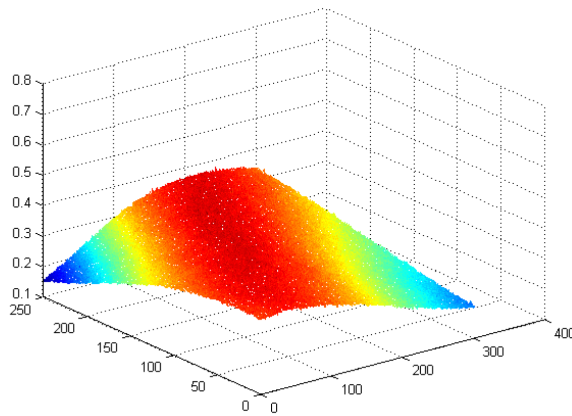


Environment simulation and test

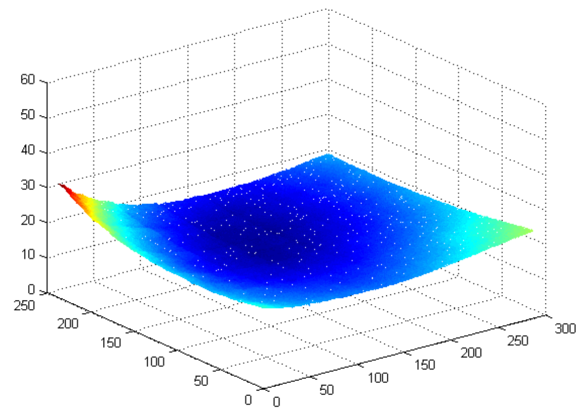
DPC: field experiment



1(a) Experiment site

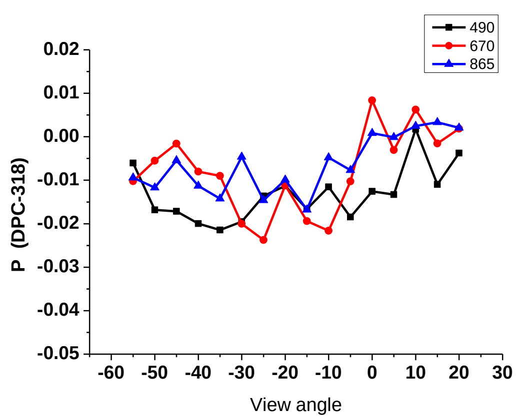


(2a)Sky polarization of 670nm

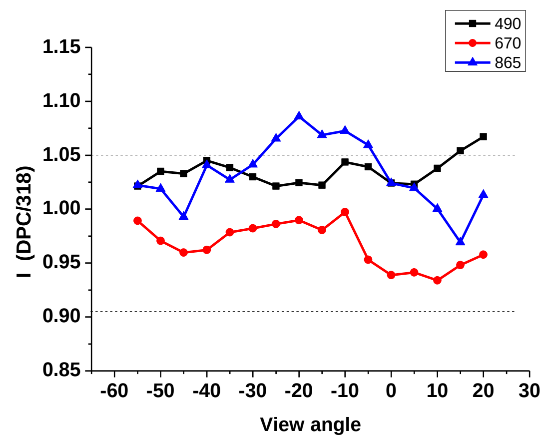


(3a) Sky radiance of 670nm

(1b)Original image



(2b) Polarization difference with CE318



(3b) Radiance difference with CE318

The comparison results with CE318: Polarization difference <2%, Radiance difference average< 5%.

DPC vs POLDER-3

	POLDER/PARASOL	DPC
Operation Mode	• Frame imaging • Wide field of view imaging optical system • Polarizer and spectral filters, Acquisition of information of spectral and polarization channels	The same as the left
Detector	• CCD matrix(242 X 274)	CCD matrix(512 X 512)
Channel	• Visible-Near infrared band • Three Polarized Channel + 5 Non-polarized Channel	The same as the left
FOV	• －50° ～＋50°	The same as the left
IFOV	• 6 X 7 km	3.29 km

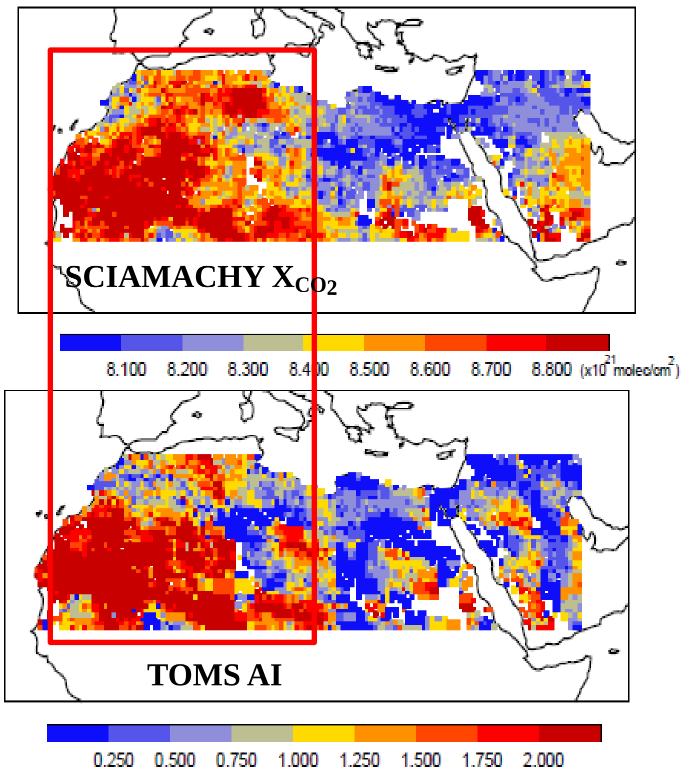
DPC: Proposed L2 products

Retrieved parameter	Sensor	Temporal Coverage
Aerosol		
• Aerosol optical thickness (AOT) • Angstrom exponent • Backscattering coefficient • Non-sphericity index	DPC	1 file/orbit
Water vapor and clouds		
• Cloud fraction • Cloud thermodynamic phase • Cloud optical thickness • Cloud oxygen pressure • **Cloud effective radius** • Water vapor integrated content	DPC	1 file/orbit

Part2: Retrieval Method

Challenge：How to account for aerosol scattering？

Correlation between CO2 retrieval and Aerosol Index (AI)

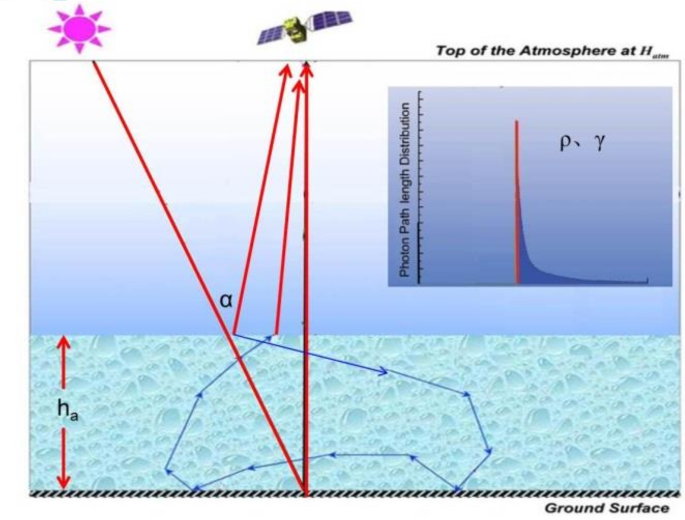


—— Houweling et al.（2005）

Frequent air pollution events with high aerosol optical depth.

Photon path-length Probability Density Function

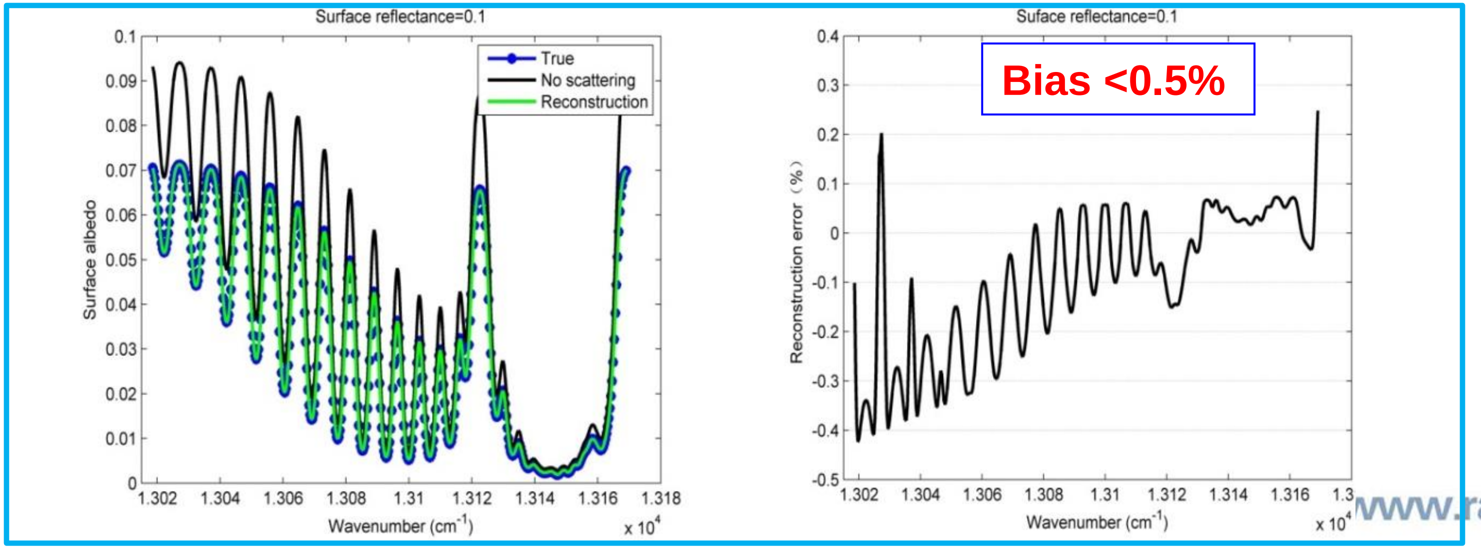
PPDF: using 4 factors to modify the RTM (Brill.,et al,2007)**:**



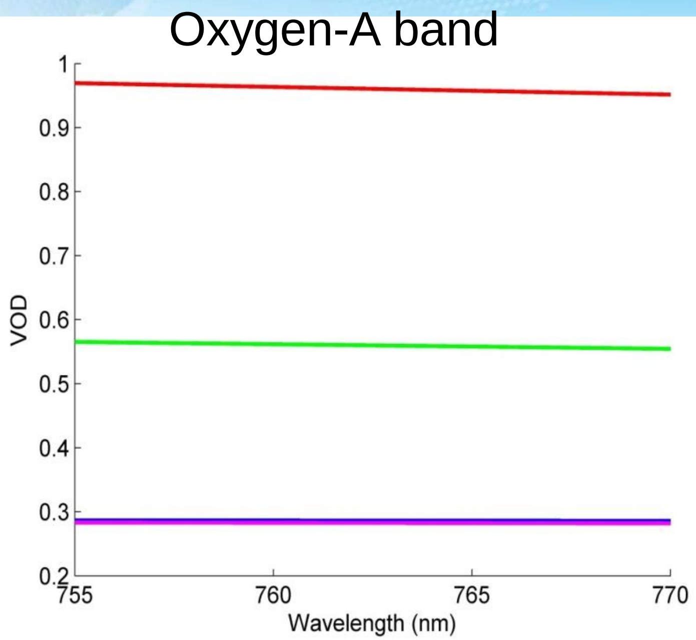
$$\tilde{T} = \alpha \cdot T_2 + (1-\alpha) \cdot T_1 \cdot T_2$$

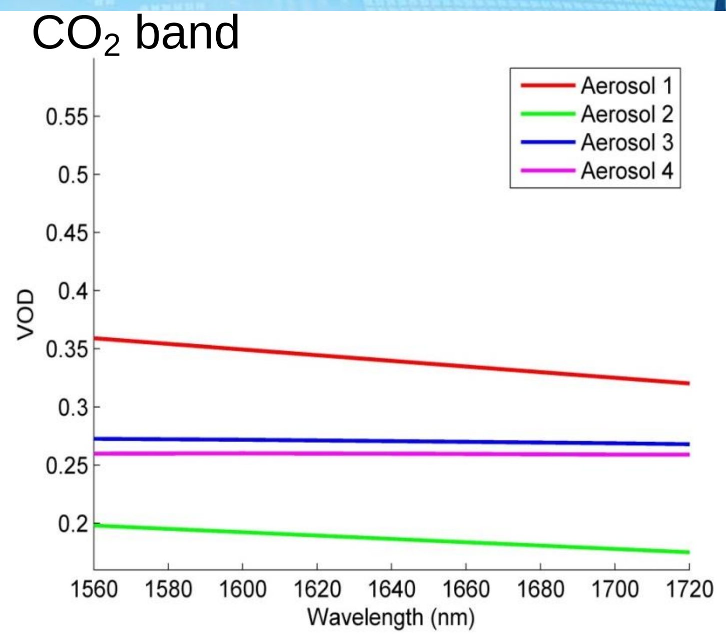
$$T_1 = \exp\left[-\left(\frac{1}{\mu} + \frac{1}{\mu_0}\right) \cdot (1+\delta) \cdot \tau_1\right]$$

$$T_2 = \exp\left[-\left(\frac{1}{\mu} + \frac{1}{\mu_0}\right) \cdot \tau_2\right]$$

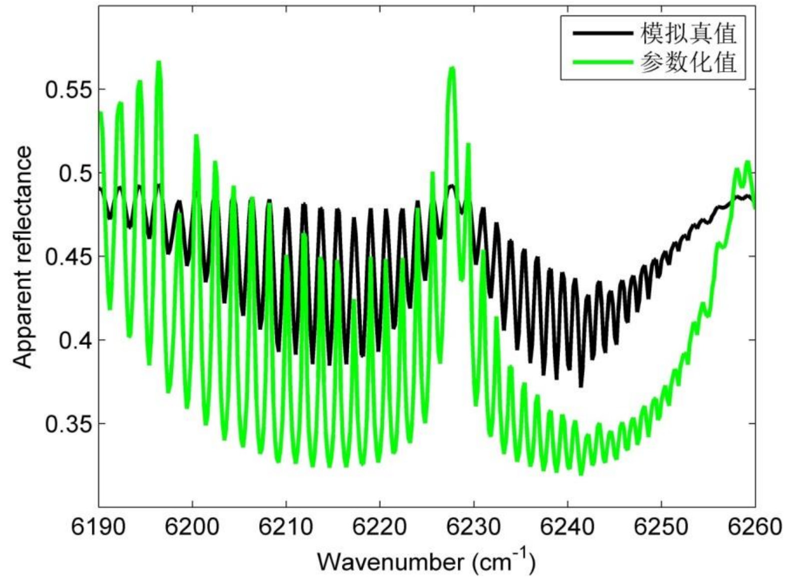


How to apply to GHGs band?

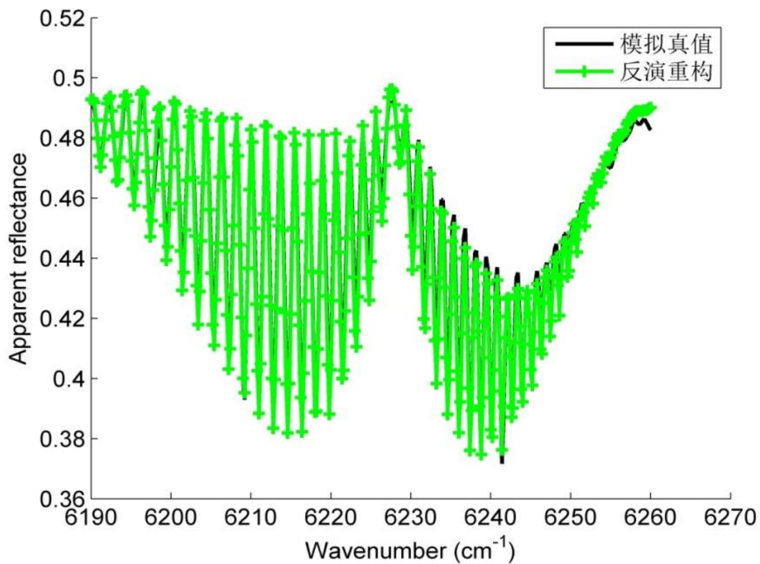




applied directly to CO_2 band：



Synchronous retrieval：

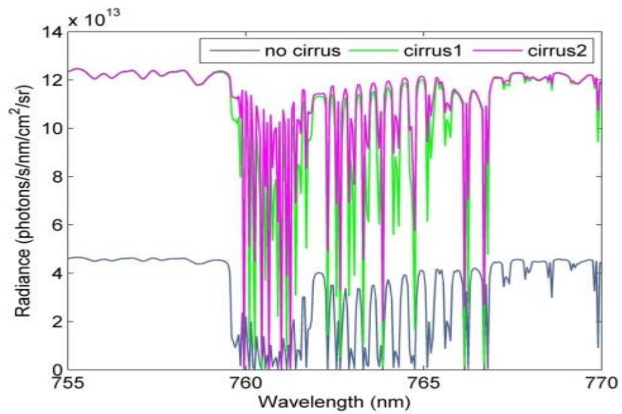


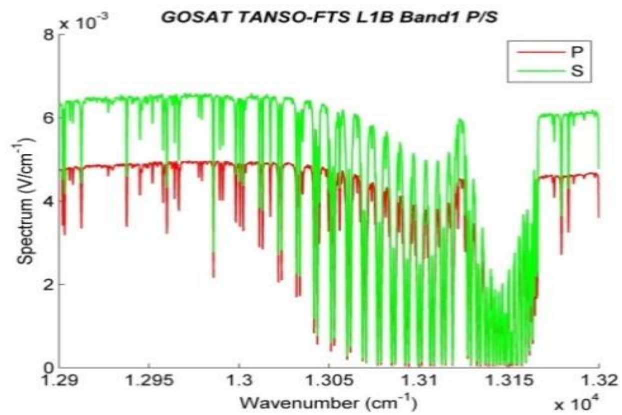
Cloud detect

Step 1: using O2-A Band to judge if scattering exist ?

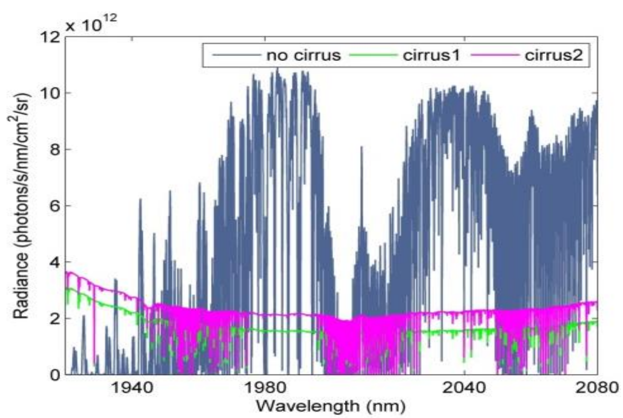
Step2: if Step 1 yes, determine aerosol or cloud based on the spectral characteristic of both O2-A Band and 2.0 um Band

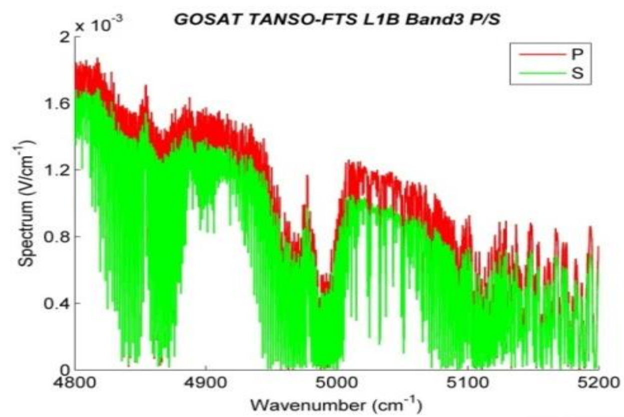
O2-A Band





2.0μm Band





Optimal Estimation Algorithm

Observation Y,

$$Y = F(X) + \varepsilon$$

Cost function：

$$J(X') = \|Y - F(X')\| = \min$$

iteration（*Rodgers*,2000），**expressed as：**

$$\mathbf{x}_{i+1} = \mathbf{x}_i + \left[\mathbf{S}_a^{-1} + \mathbf{K}_i^T \cdot \mathbf{S}_e^{-1} \cdot \mathbf{K}_i\right]^{-1} * \{\mathbf{K}_i^T \cdot \mathbf{S}_e^{-1}[\mathbf{y} - \mathbf{F}(\mathbf{x})] - \mathbf{S}_a^{-1}[\mathbf{x}_i - \mathbf{x}_a]\}$$

To stabilize the iteration:

$$X_{i+1} = X_i + \alpha\left[K_i^T \cdot S_e^{-1} \cdot K_i + S_a^{-1} + \gamma \cdot I\right]^{-1} * \{K_i^T \cdot S_e^{-1}[Y - F(X)] - S_a^{-1}[X_i - X_a]\}$$

modified damped newton method（MDNM）

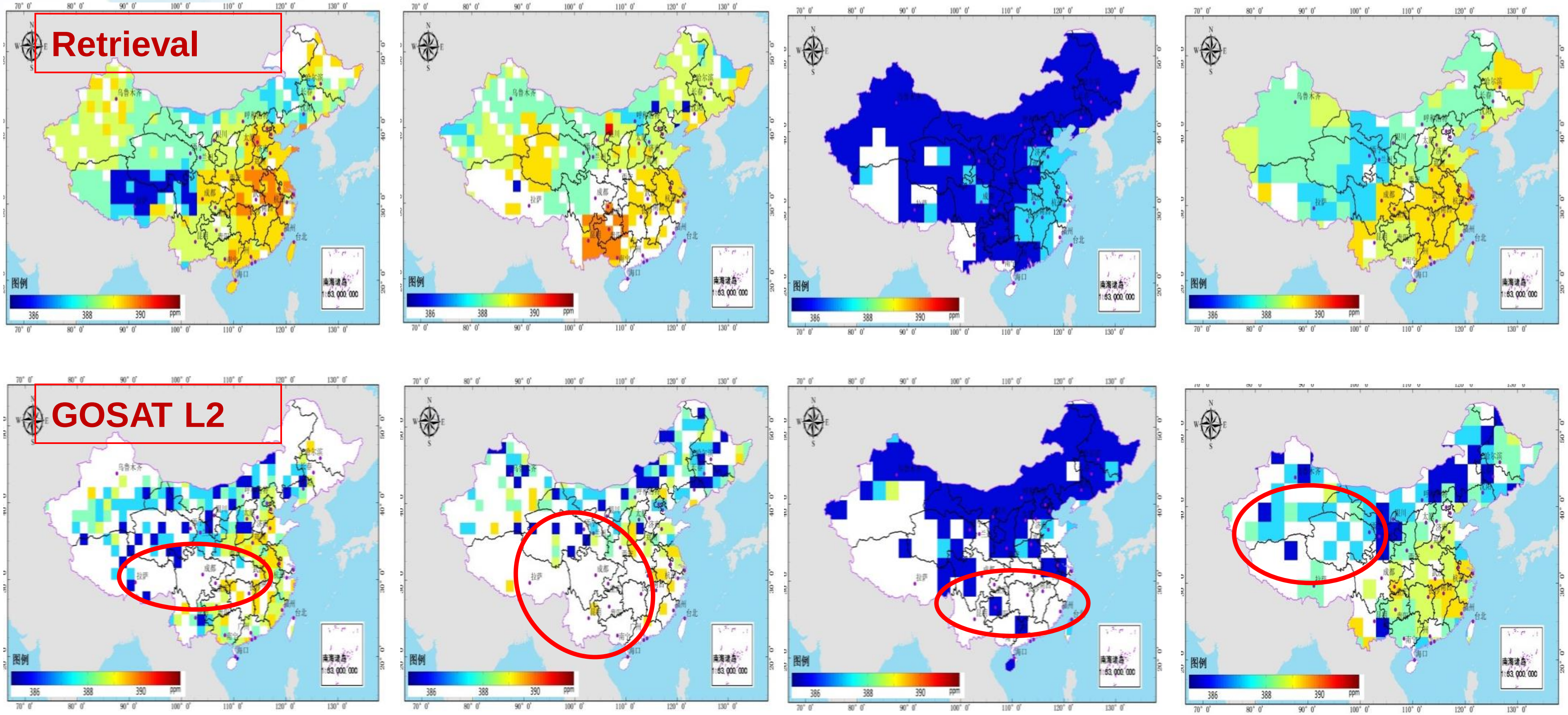
Mingmin Zou et al., 2016

Retrieval result

RADI

Comparing to GOSAT CO_2 L2 product（2010）

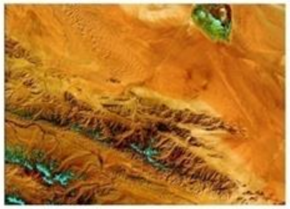
1~3月 4~6月 7~9月 10~12月

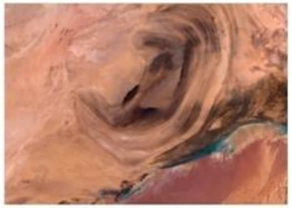


Summary

- GaoFen mission overview and introduction to GMI and DPC onboard GaoFen-5
- PPDF-based method to account for aerosol scattering
- Fast cloud screening method
- GHG retrieval results from GOSAT L1 data

Thanks!



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