Improving atmospheric CO_2 retrieval based on the collaborative use of GMI and DPC on Chinese hyperspectral satellite GF5-02

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The Greenhouse gases Monitoring Instrument (GMI) on Chinese hyperspectral satellite GF5-02 can provides more abundant observations of global atmospheric CO_2 which plays an important role in climate research. CO_2 retrieval precision is the key to determine the application value of the GMI. In order to reduce the influence of atmospheric scattering, we combined the Directional Polarimetric Camera (DPC) data on the same satellite to improve the anti-interference ability of GMI's CO_2 retrieval and ensure its retrieval precision. To realize the reliability and feasibility of the collaborative use of GMI and DPC, we designs the pointing registration method of the GMI based on the coastline observations, the spatial resolution matching method and the collaborative cloud screening method of the GMI and DPC observations. With the combination of DPC which supplied the spectral data and aerosol product, the retrieval ability of the Coupled Bidirectional reflectance distribution function CO2 Retrieval (CBCR) method developed for GMI CO_2 retrieval was improved as the retrieval efficiency of CO_2 products increased by 27% and the CO2 retrieval precision increased from 3.3 ppm to 2.7 ppm. Meanwhile, the collaborative use not only guaranteed the GMI's ability to detect global and area CO_2 concentration distribution characteristics like the significant concentration differences between the northern and southern hemispheres in winter and high CO_2 concentration in urban agglomeration areas caused by human activities, but also extended GMI's potential of monitoring anomalous events like Tonga volcanic eruption.

1. Introduction

- **The Chinese hyperspectral satellite GF5-02 launched on 7 September 2021 is equipped with a Greenhouse Gas Monitoring Instrument(GMI), Directional Polarimetric Camera (DPC) which aims to monitor global environment.**
- **GMI observes CO_2 and CH_4 through solar light reflected from the Earth's surface.**
- **DPC observes cloud and aerosol through images of the intensity spectrum and polarization spectrum.**
- **Accurate cloud and aerosol supplied by DPC is benefit for GMI's CO_2 retrieval. However, the GMI and DPC are not coaxially designed, and there is a certain deviation in attitude during the process of assembly and adjustment and satellite platform operation. It is difficult to determine the relative position of the GMI and DPC accurately.**

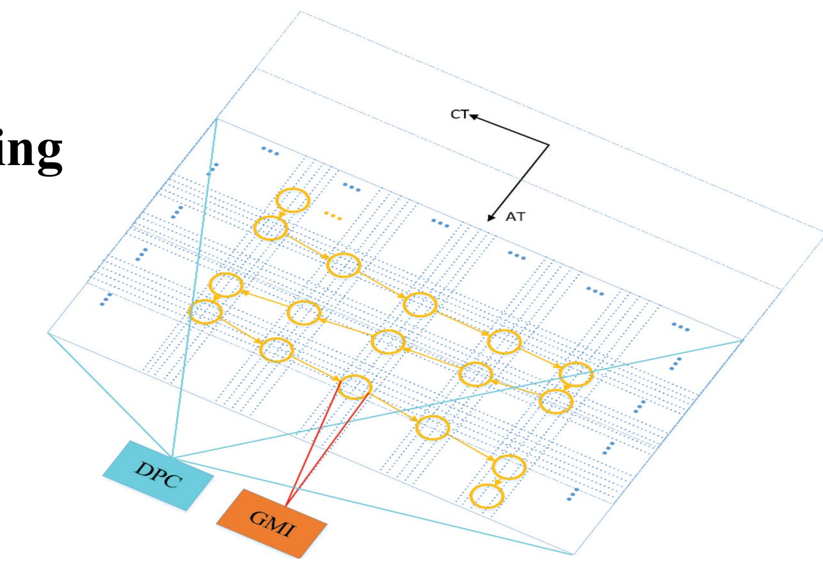

Fig.1 Spatial relationship of GMI and DPC

2. Objective

- **Solving the pointing deviation problem of GMI and DPC and designing the collaborative use method to improve GMI's CO_2 retrieval ability.**
- **Exploring GMI application potential on Global CO_2 observation and other aspects.**

3.1. GMI and DPC Collaborative use methods

1) GMI pointing registration

2) Spatial resolution matching

3) Collaborative cloud screening

- L1 test

$R_{490}^{mes} - R_{490}^{mol} \geq \Delta R_{t1}$

- L2 test

$R_{490}^{mes} - R_{490}^{mol} \geq \Delta R_{t2}$

$(R_{865}^{mes} - R_{865}^{mol}) - (R_{670}^{mes} - R_{670}^{mol}) \geq \Delta m$

- L3 test

$(u_s + u_v) R_{865p}^{\Theta} > \Delta R_p^{t1}$

- L4 test

$\Delta P = |P_0 - P_s| \geq \Delta P_t \ln(\chi^2) \geq \chi_t^2$

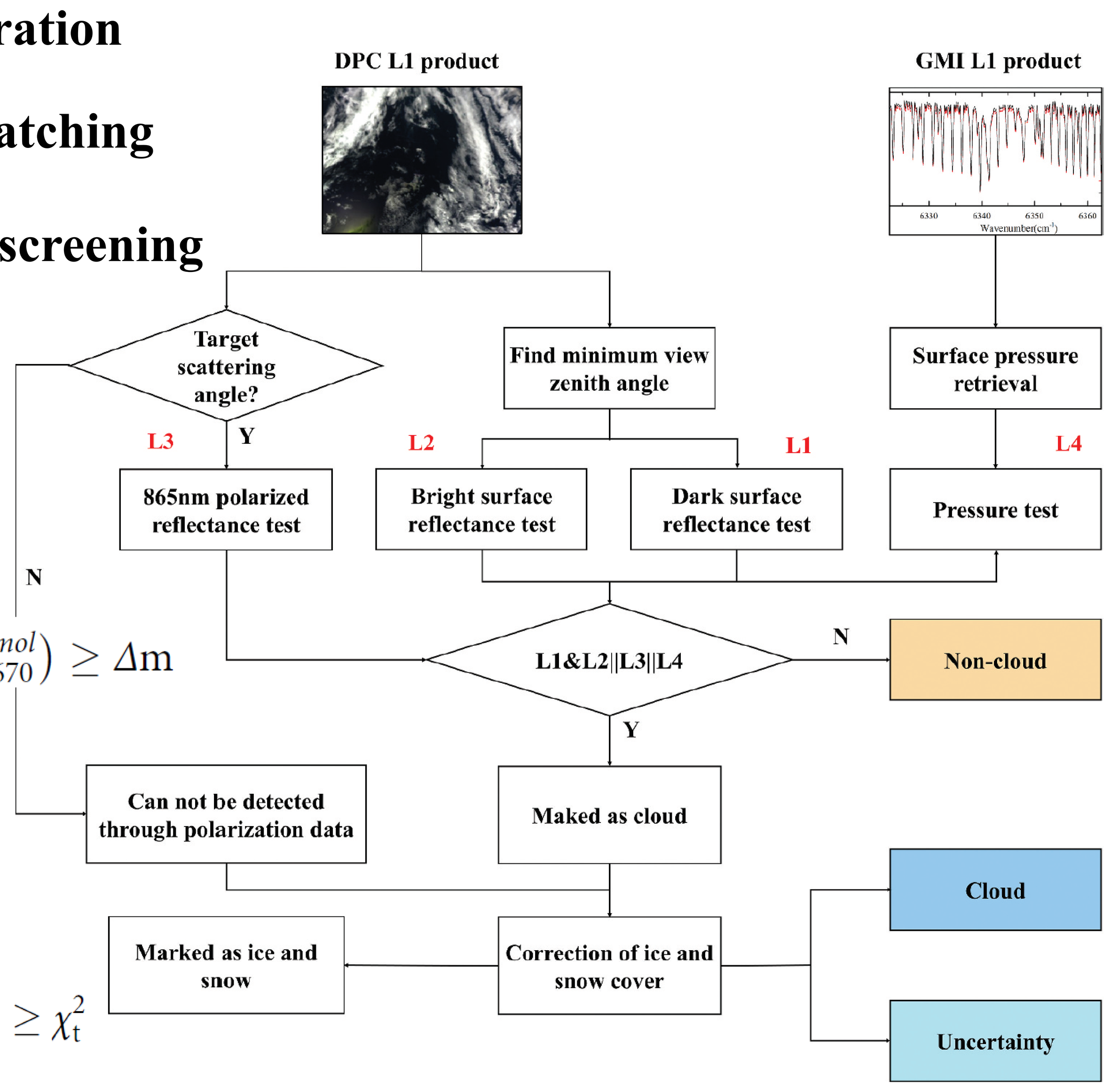

Fig.2 GMI and DPC collaborative use method

3.2. Retrieval method

- **The CBCR method adopts the optimal estimation method as following**

$$x_{i+1} = x_i + \left(K_i^T S_\varepsilon^{-1} K_i + (1+\gamma) S_a^{-1}\right)^{-1} \left[K_i^T S_\varepsilon^{-1}(y - F(x)) + S_a^{-1}(x_a - x_i)\right]$$

- **The forward model coupled with Ross-Li bidirectional reflectance model and global seasonal aerosol types.**

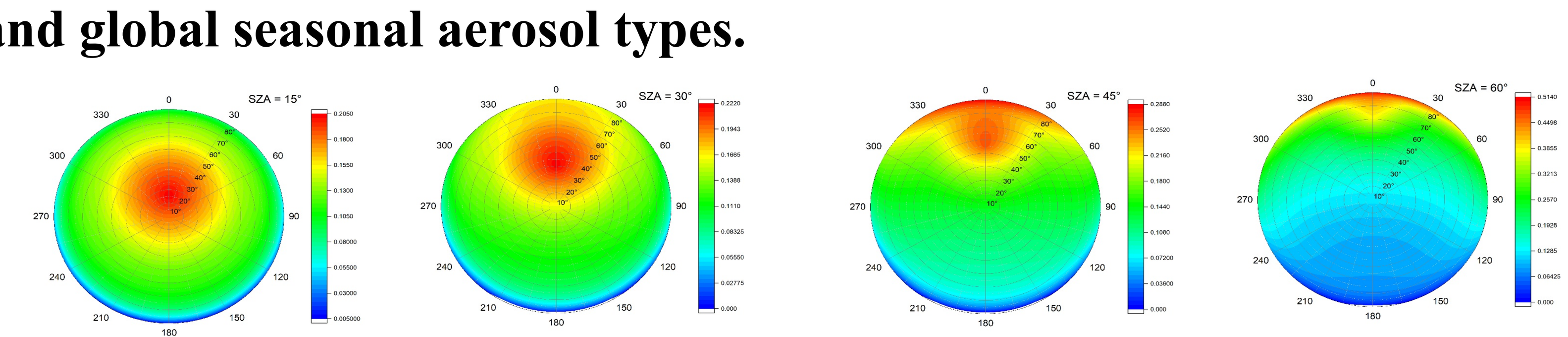

Fig.3 Surface BRDF model maps corresponding to the underlying urban surface in different solar zenith angles . 15° (a), 30° (b), 45° (c) and 60° (d)

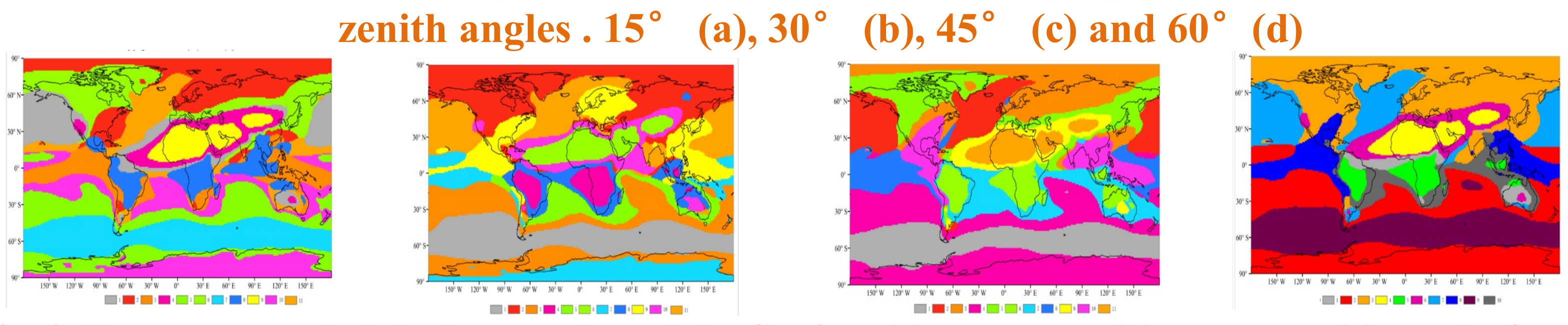

Fig.4 Four seasonal global aerosol models. Spring (a), summer (b), autumn (c), and winter(d)

4. Ability analysis

- **Product number**

Table 1. The product number during the retrieval process.

	L1 products	L1 products after cloud screening	CO_2 products	Retrievable data screening efficiency
Collaborative use	38000	9600	8400	88%
Without collaborative use	38000	13200	8070	61%

- **Retrieval precision**

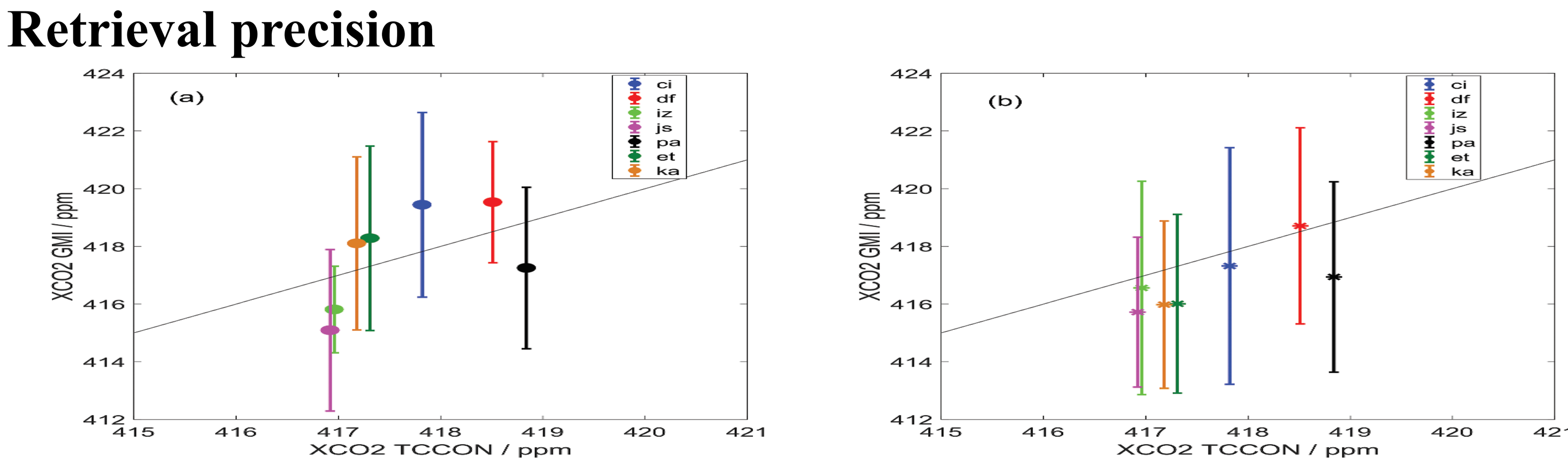

Fig.5 (a) GMI XCO2 retrieval with combination of DPC. (b) Same as (a) but without DPC.

5. GMI application potential

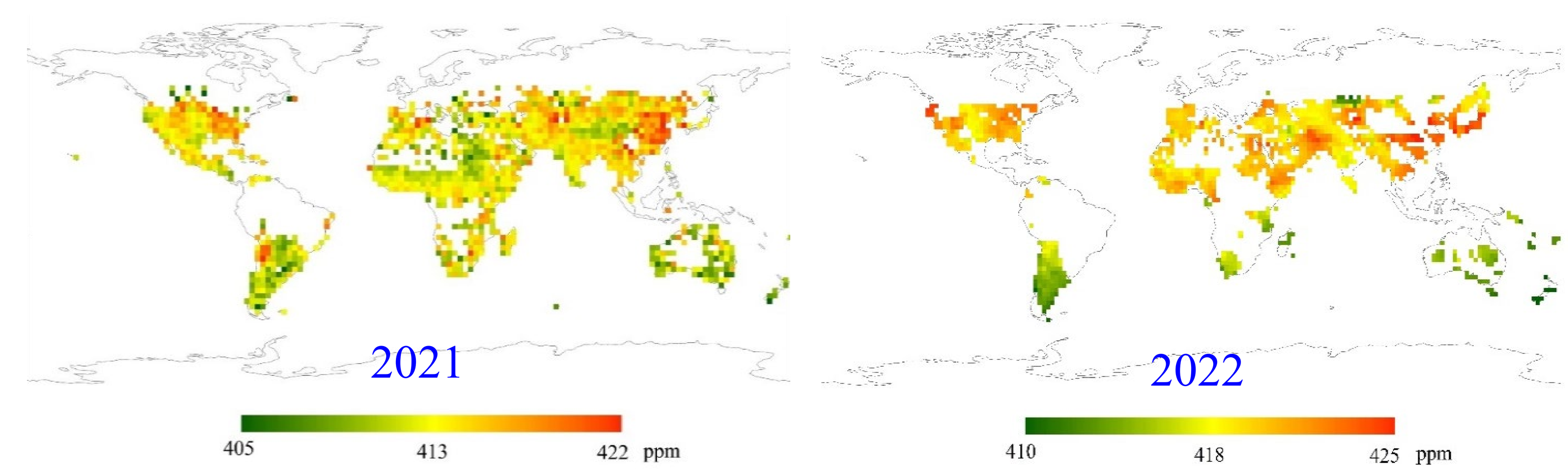

Fig.6 GF5–2 GMI global CO_2 retrieval results in the winter of 2021 and 2022.

- **Global observation: a significant difference in CO_2 concentrations between the Northern and Southern hemisphere, the spatial characteristics of CO_2 caused by human activities, and the annual increase.**
- **Anomalous event observation: a weak CO_2 enhancement signal over the land area affected by the Tonga volcanic from days 13 to 15 in January 2022.**

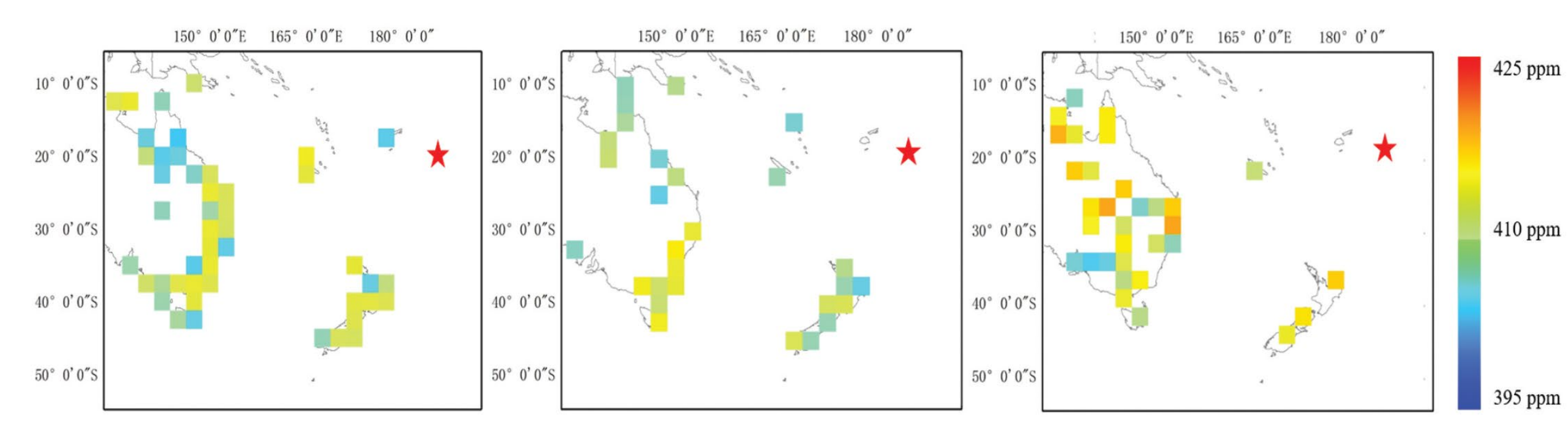

Fig.7 (a) CO_2 concentration near the volcano observed by the GF5–01 GMI in January 2019. (b) Same as (a) but in January 2020. (c) Same as (a) but by the GF5–02 GMI in January 2022

6. Conclusions

- **Through joint cloud detection by the GMI and DPC, the efficiency of CO_2 retrieval products increase by 27%, saving considerable calculation time, and the retrieval precision has improved from 3.3 ppm to 2.7 ppm.**
- **GMI can monitor the temporal and spatial features of global CO_2 and detect the CO_2 abnormal fluctuation like Tonga volcanic eruption.**