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First Global Carbon Dioxide Maps Produced from TanSat Measurements

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1. The need for global carbon monitoring from space and the TanSat mission

Global warming is a major problem, for which carbon dioxide (CO_2) is the main greenhouse gas involved in heating the troposphere. However, the poor availability of global CO_2 measurements makes it difficult to estimate CO_2 emissions accurately. Satellite measurements would be very helpful for understanding the global CO_2 flux distribution if the CO_2 column-averaged dry-air mole fraction (XCO_2) could be measured with a precision of 1–2 ppm (Baker et al., 2010). The Greenhouse Gases Observing Satellite (GOSAT) (Yokota et al., 2009; Yoshida et al., 2013; Kuze et al., 2014) was launched in 2009, followed by the Orbiting Carbon Observatory 2 (OCO-2) (Eldering et al., 2016; Crisp et al., 2017; Bösch et al., 2011) in 2014. Tansat, a Chinese Earth observation satellite dedicated to monitoring CO_2, was launched in December 2016 and is the third satellite capable of monitoring greenhouse gases by hyper-spectral near-infrared/shortwave infrared (NIR/ SWIR) measurement.

The TanSat mission was supported by the Ministry of Science and Technology of China, the Chinese Academy of Sciences, and the China Meteorological Administration. TanSat is an agile, sun-synchronous satellite that operates in three observation modes—namely, the nadir, sun-glint, and target modes. The line of sight tracks the principal plain in nadir mode and the glint in sun-glint mode, which increases the incident signal level and guarantees high performance of the charge-coupled device (Liu et al., 2013a; Cai et al., 2014). The Atmospheric Carbon dioxide Grating Spectroradiometer (ACGS) was designed to measure near-infrared/shortwave infrared backscattered sunlight in the molecular oxygen A-band (0.76 μm) and two CO_2 bands (1.61 and 2.06 μm) (Wang et al., 2014; Li et al., 2017; Zhang et al., 2017). The Cloud and Aerosol Polarization Imager (CAPI) measures in ultraviolet, visible, and NIR regions to improve the information on aerosol optical properties and the cloud mask for the CDS measurements (Chen et al., 2017a, 2017b; Wang et al., 2017).

2. In-orbit CO_2 measurements from TanSat

After TanSat was launched in December 2016, in-orbit and calibration tests were completed in the summer of 2017, and the performance of the instrument has since been evaluated in test sessions. TanSat XCO_2 retrieval algorithm was developed based on Institute of Atmospheric Physics Carbon dioxide retrieval Algorithm for Satellite remote sensing, referred to as IAPCAS (Yang et al., 2015). IAPCAS also informed the development of ATANGO (Application of TanSat XCO_2 Retrieval Algorithm in GOSAT Observations). Its retrieval accuracy and precision have been validated by Total Carbon Column Observing Network (TCCON) measurements (Liu et al., 2013b; Yang et al., 2015), and the retrieval product has been applied in estimations of carbon flux inversion in China (Yang et al., 2017). The retrieval relies on mathematical and physical models to approach XCO_2 from hyper-spectrum measurements restored in the L1B data. The result is the best estimate after comparison between the simulated satellite-received spectrum and measurements. The first global XCO_2 maps based on TanSat measurements show the global distribution over land in April and July 2017 (Fig. 1).

Based on the maps, a seasonal decrease in CO_2 concentration from spring to summer in the Northern Hemisphere is obvious, and results from a change in the rate of photosynthesis. This effect is also reflected in the XCO_2 gradient between the Northern Hemisphere and Southern Hemisphere shown in Fig. 1a. Emission hotspots due to anthropogenic activity, such as industrial activity and fossil fuel combustion, are clearly evident in eastern China, the eastern United States, and Europe, as reflected by the relatively high levels of XCO_2.

3. Outlook

There are still gaps in the TanSat measurements between the footprints of each orbit, and these missing measurements also continue to impact on the carbon flux inversion estimation (Feng et al., 2009). The gaps can be filled by using both OCO-2 and TanSat XCO_2 measurements because the footprint tracks are almost parallel and interlaced, such that

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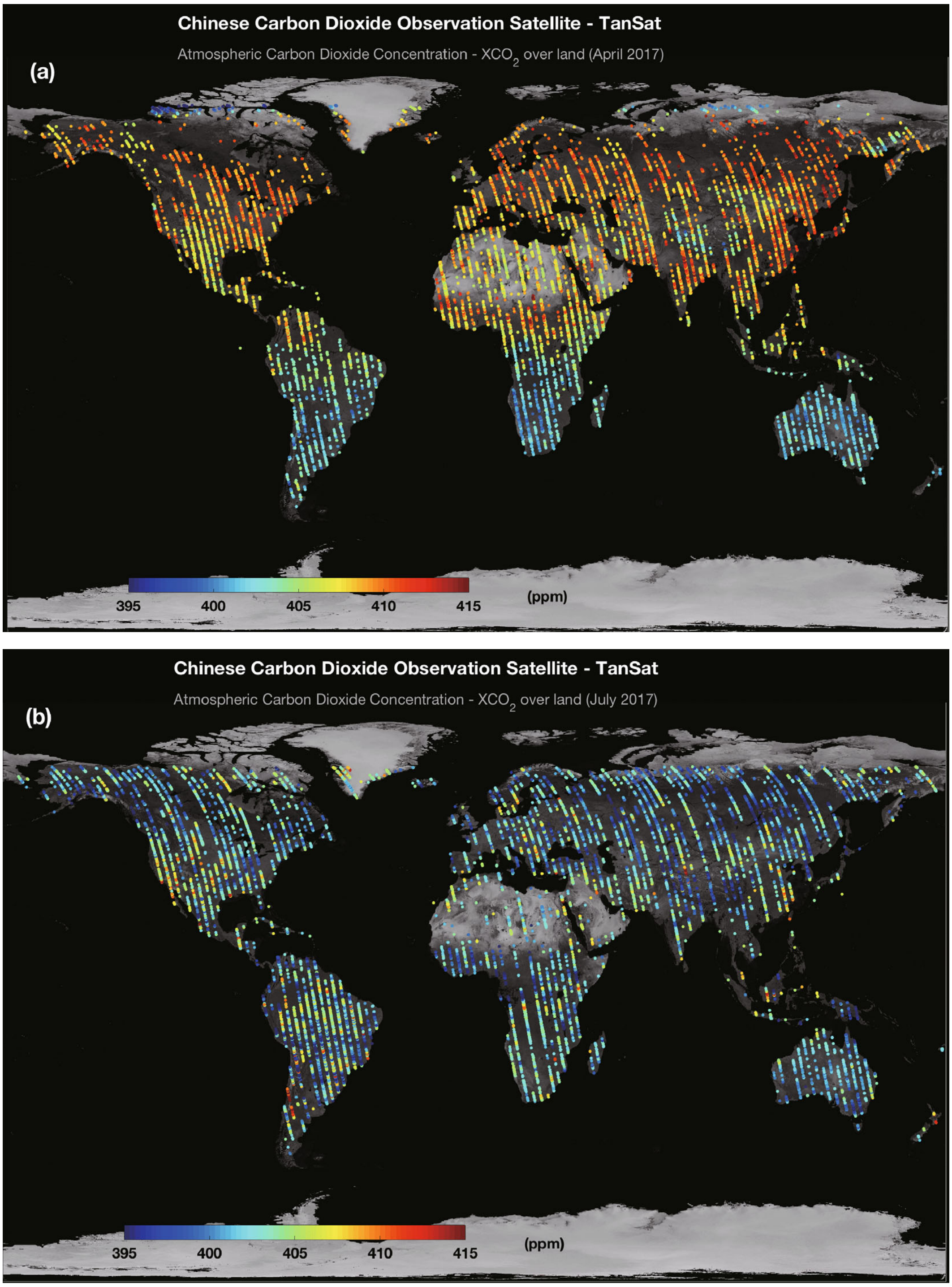

Fig. 1. Global XCO_2 maps produced from TanSat in nadir mode in (a) April and (b) July 2017. The colored marks indicate the XCO_2 values and the color scale bar is shown at the bottom of each figure.

OCO-2 provides an additional measurement track between two TanSat tracks. This improves the spatial coverage significantly when compared with the use of a single satellite (i.e., either OCO-2 or TanSat). Accuracy and precision of XCO_2 data are essential for the joint application of OCO-2 and TanSat data. Hence, research focusing on the validation of satellite in-orbit calibration and retrieval algorithms is required to evaluate their precision and reduce the bias associated with their use.

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