Towards high Precision XCO2 Retrievals from TanSat Observations

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5 Colorado State University, Fort Collins, CO, USA
The TanSat Mission

- National High Technology Research & Development Programs by Ministry of Science and Technology of China (MOST) (2011-2017)
- Strategic Priority Research Program from Chinese Academy of Sciences
  - Climate Change: Carbon Budget and Relevant Issue
  - Space Science: Scientific Research Satellite
- NSMC (CMA) -- (2016- NOW), Ground segment— Satellite data receive and process

**Term-1**
Measurement Goals
XCO₂
1~4 ppmv
Monthly
500 x 500 km²

**Term-2**
Measurement Goals
CO₂ Flux
Relative flux error 20%
Monthly
500 x 500 km²

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*TanSat mission kicked-off at 2011, launched at 2016*

*TanSat mission will join the ESA 3rd Party mission*
TanSat & Instrument

Cloud and Aerosol Polarization Imager - CAPI
- A wide field multi-band imager with polarization channels
- UV: 0.38μm; VIS: 0.67μm; NIR: 0.87, 1.375 and 1.64μm
- Polarization: 0.67 & 1.64 μm

Atmospheric Carbon Dioxide Grating Spectrometer - ACGS
- Hyperspectral grating spectrometer with 3 bands

<table>
<thead>
<tr>
<th>Name</th>
<th>Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit type</td>
<td>sun-synchronous</td>
</tr>
<tr>
<td>Altitude</td>
<td>700 km</td>
</tr>
<tr>
<td>Inclination</td>
<td>98°</td>
</tr>
<tr>
<td>Local time</td>
<td>13:30</td>
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<tr>
<td>Weight</td>
<td>500Kg</td>
</tr>
</tbody>
</table>

TanSat & Instrument

Principal plane

Nadir mode

Sun-glint mode

Target mode
L2 Retrieval Algorithms

IAPCAS

TanSat algorithm

ATANGO

ATG-OCO

TanSat

Observation design

Retrieval algorithm

Observation simulation

Computation test

Carbon flux inversion

TanSat

Incoming Spectra

Standard Retrieval Process

XCO2 Product

Sodankylä, Finland
Braly, Czech Republic
Bremen, Germany
Karlsruhe, Germany
Orleans, France

Parker Falls, Wisconsin, USA
Lamont, Oklahoma, USA
Tsukuba, Ibaraki, Japan
Lauder, New Zealand
Lauder, New Zealand

Garmisch, Germany

Bialystok, Poland

IAPCAS

UoL-FP

GOSAT XCO2 (ppmv)

TCCON GGG2014 XCO2 (ppmv)

Wollongong

Darwin

Garmisch

Bialystok

Izana

Lamont

ParkFalls

Saga

Lauder

Here, a 2-band retrieval (NIR + 1.6 μm CO2 band) is used for IAPCAS and UoL-FP

(Yang et al., 2018, Liu et al., 2018)

(Parker et al., 2013; Cogan et al., 2012; Boesch et al., 2013; Somkuti et al., 2018)

EGU General Assembly 2020
Preliminary Result: Comparison of Retrieval Results from Original L1B Data

Retrieval comparison between

UoL-FP .VS. IAPCAS

Case study, TanSat 8 Oct. 2017, around Lamont with almost cloud free condition

- Large spread of XCO2 retrieval results
- Poor consistency between different TanSat footprints (FP1-FP8)
- Large differences between UoL-FP and IAPCAS retrievals
Analysis of TanSat Solar Measurements

- A persistent frequency pattern is observed in O$_2$ A band when compared to UoL-FP solar model
- A Fourier series correction has been developed for radiometric correction
  - Method minimizes residual pattern when solar measurements are analyzed

Yang et al. 2020 (submitted to JGR)
Impact of L1B Correction Method on XCO2 Retrievals

- New method for radiometric correction of TanSat L1b measurement leads to much improved the fitting residual and consistency of the XCO2 retrieval.

TanSat overpass over Lamont

8 Oct. 2017
Impact of L1B Correction Method on XCO2 Retrievals

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Filtering and Bias Correction

Application of Target Genetic algorithm for quality filtering of TanSat retrievals:
- Pre-selects transparency and complexity based on candidate filters selected according to correlation of error against TCCON
- Transparency of ~65% and 2 ppm RMSE can be achieved with 5 filters
- Empirical selection results in additional 13.5% loss of data

Bias correction based on multi-linear regression of same 5 parameters against TCCON

![Graphs showing the application of TGA for different number filters and manual selection](image)
Validation of UoL-FP XCO$_2$ against TCCON

- Good comparisons of UoL-FP TanSat retrieval against TCCON similar to other missions (OCO-2, GOSAT)
Good comparisons of UoL-FP TanSat retrieval against TCCON similar to other missions (OCO-2, GOSAT)

<table>
<thead>
<tr>
<th>Site</th>
<th>N (overpasses)</th>
<th>bias (ppm)</th>
<th>RMSE (ppm)</th>
</tr>
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<tbody>
<tr>
<td>Bialystok, Poland</td>
<td>2</td>
<td>0.78</td>
<td>0.93</td>
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<tr>
<td>Bremen, Germany</td>
<td>1</td>
<td>-0.29</td>
<td>0.29</td>
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<tr>
<td>Burgos, Philippines</td>
<td>2</td>
<td>0.27</td>
<td>1.10</td>
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<tr>
<td>Darwin, Australia</td>
<td>12</td>
<td>0.29</td>
<td>1.36</td>
</tr>
<tr>
<td>East Trout Lake, Canada</td>
<td>19</td>
<td>0.21</td>
<td>1.12</td>
</tr>
<tr>
<td>Edwards, USA</td>
<td>3</td>
<td>1.36</td>
<td>1.39</td>
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<tr>
<td>Garmisch, Germany</td>
<td>5</td>
<td>0.24</td>
<td>1.18</td>
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<td>JPL, USA</td>
<td>20</td>
<td>-1.12</td>
<td>1.39</td>
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<td>Karlsruhe, Germany.</td>
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<td>0.33</td>
<td>1.67</td>
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<td>Lamont, USA</td>
<td>17</td>
<td>0.37</td>
<td>0.76</td>
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<td>Lauder, New Zealand</td>
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<td>1.19</td>
<td>1.40</td>
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<tr>
<td>Orléans, France</td>
<td>2</td>
<td>1.40</td>
<td>1.83</td>
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<td>Paris, France.</td>
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<td>Park Falls, USA</td>
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<td>0.41</td>
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<td>Pasadena, USA</td>
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<td>Rikubetsu, Japan</td>
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<tr>
<td>Sodankylä Finland</td>
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<td>1.17 (0.35)</td>
<td>2.83 (1.25)</td>
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<tr>
<td>Saga, Japan</td>
<td>13</td>
<td>-0.92</td>
<td>1.53</td>
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<tr>
<td>Tsukuba, Japan</td>
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<td>-1.04</td>
<td>1.62</td>
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<tr>
<td>Wollongong, Australia</td>
<td>5</td>
<td>0.90</td>
<td>1.23</td>
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</tbody>
</table>
Inter-comparisons of TanSat UoL-FP and IAPCAS Retrieval

- Direct intercomparisons show good agreement between UoL and IAPCAS retrieval
- Note that no bias correction is applied here to both retrievals

RMSE: 1.74 ppm
BIAS: -0.55 ppm
STD: 1.66 ppm
77364 soundings
Summary and Outlook

• We have applied the UoL-FP retrieval to TanSat XCO2 retrieval over TCCON sites

• By analyzing the solar calibration measurement, we found spectral artifacts can be effectively eliminated by applying a Fourier series model for radiometric correction

• This correction significantly improves fitting residual, and accordingly reduces XCO2 retrieval RMSE against measurements from the TCCON

• After applying a bias correction and filtering, a mean RMSE of 1.47 ppm against TCCON is found with typical biases of a few tenths of a ppm for individual TCCON sites but larger biases (~1 ppm) are observed for some sites

• The methods developed in this study will be applied to IAPCAS XCO2 retrieval which is used for the operational processing of TanSat L2 data. IAPCAS data will be available on the China GEO data service (www.chinageoss.org/tansat)

• UoL-FP TanSat data will be made available via ESA CCI+ website.