Application of TanSat algorithm on GOSAT observation -ATANGO and OCO-2 XCO_2 retrieval: validation, inter-comparison and new approach

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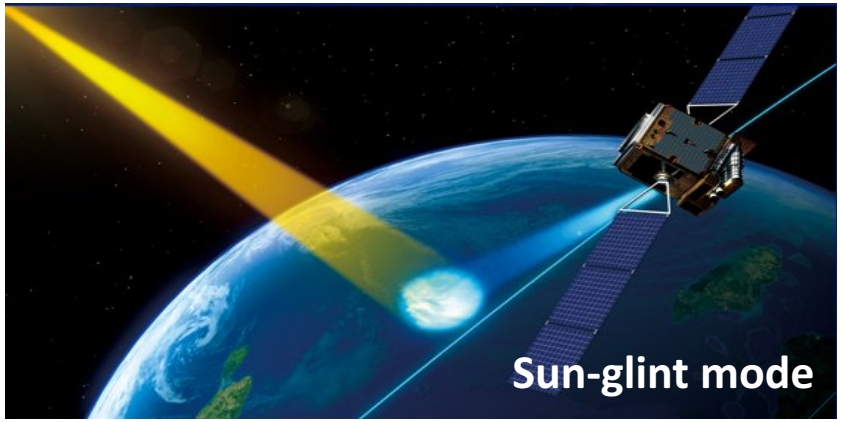
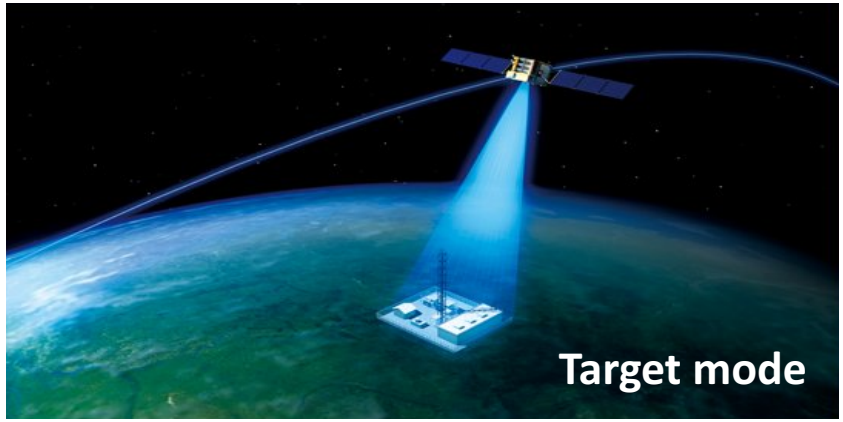
5th GOSAT RA PI program
Application of TanSat retrieval algorithm on GOSAT Observation (ATanGO)

CONTENT

TanSat: satelite





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

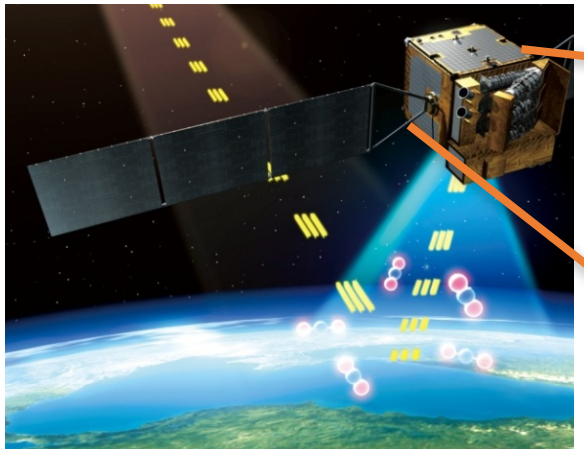
Nadir mode- Observation over land
- Push broom
- Principle plane track

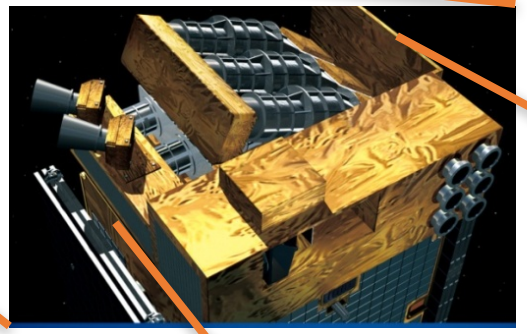
Sun-glint mode- Observation over ocean
- Sun glint track
- Principle plane track

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

TanSat

Instrument onboard TanSat



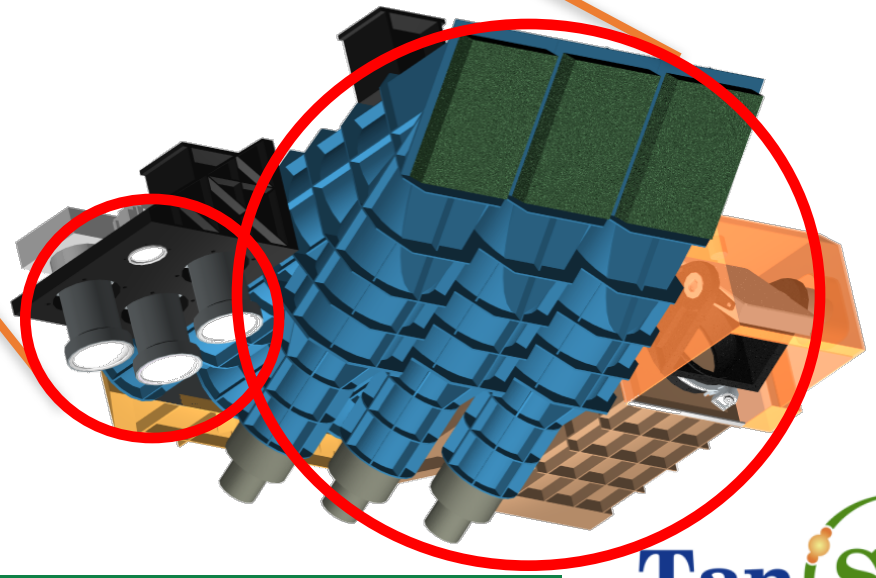


Atmospheric Carbon dioxide Grating Spectrometer-ACGS

- 0.76 μm, O2 A-band
- 1.61 and 2.06 μm, CO2 bands

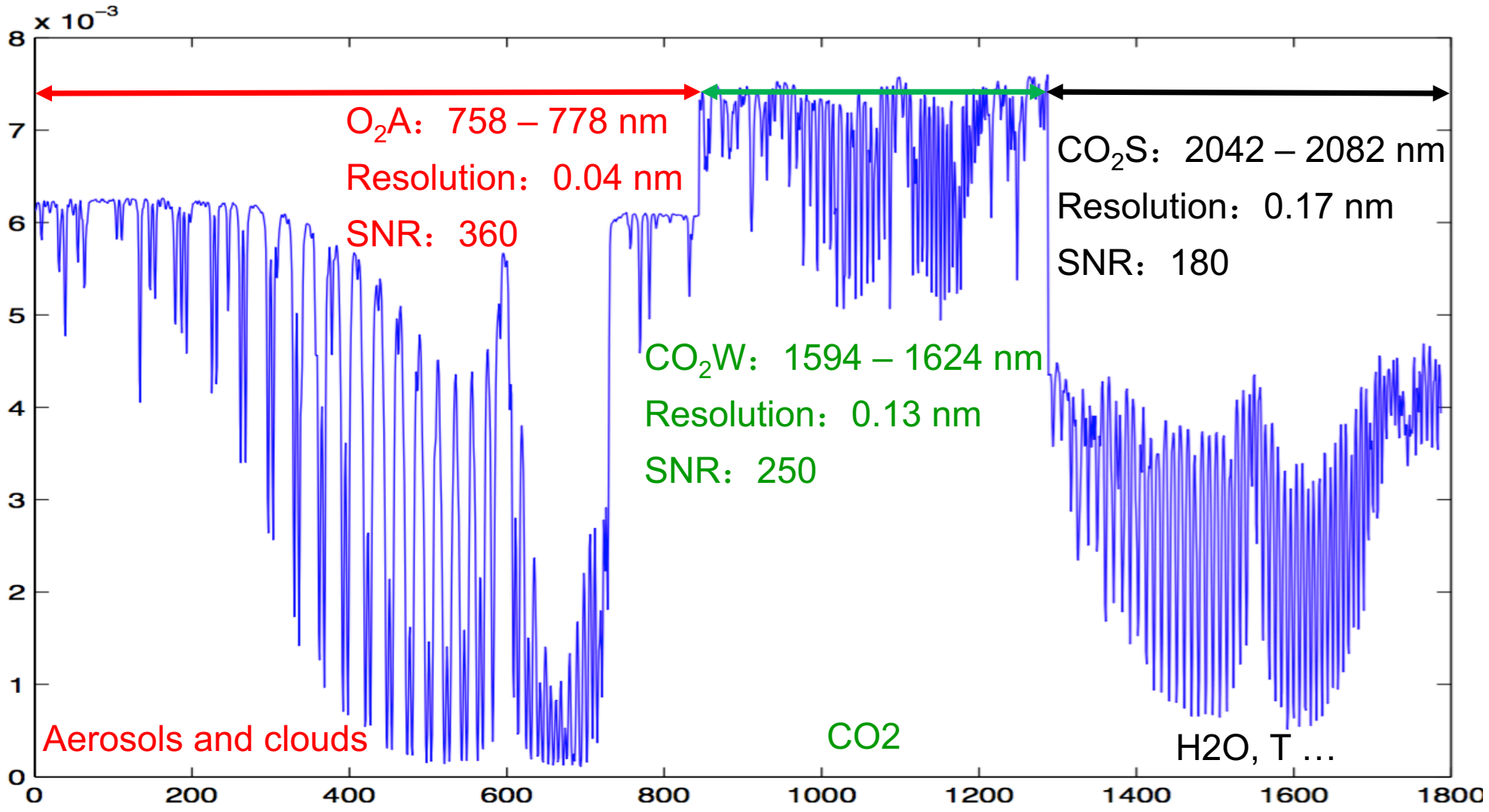
Cloud and Aerosol Polarization Imager - CAPI

- A wide field of view moderate resolution imaging spectrometer with polarization channel
- Ultraviolet: 0.38μm
- Visible: 0.67μm
- Near infrared: 0.87, 1.375 and 1.64μm
- Polarization: 0.67 & 1.64 μm



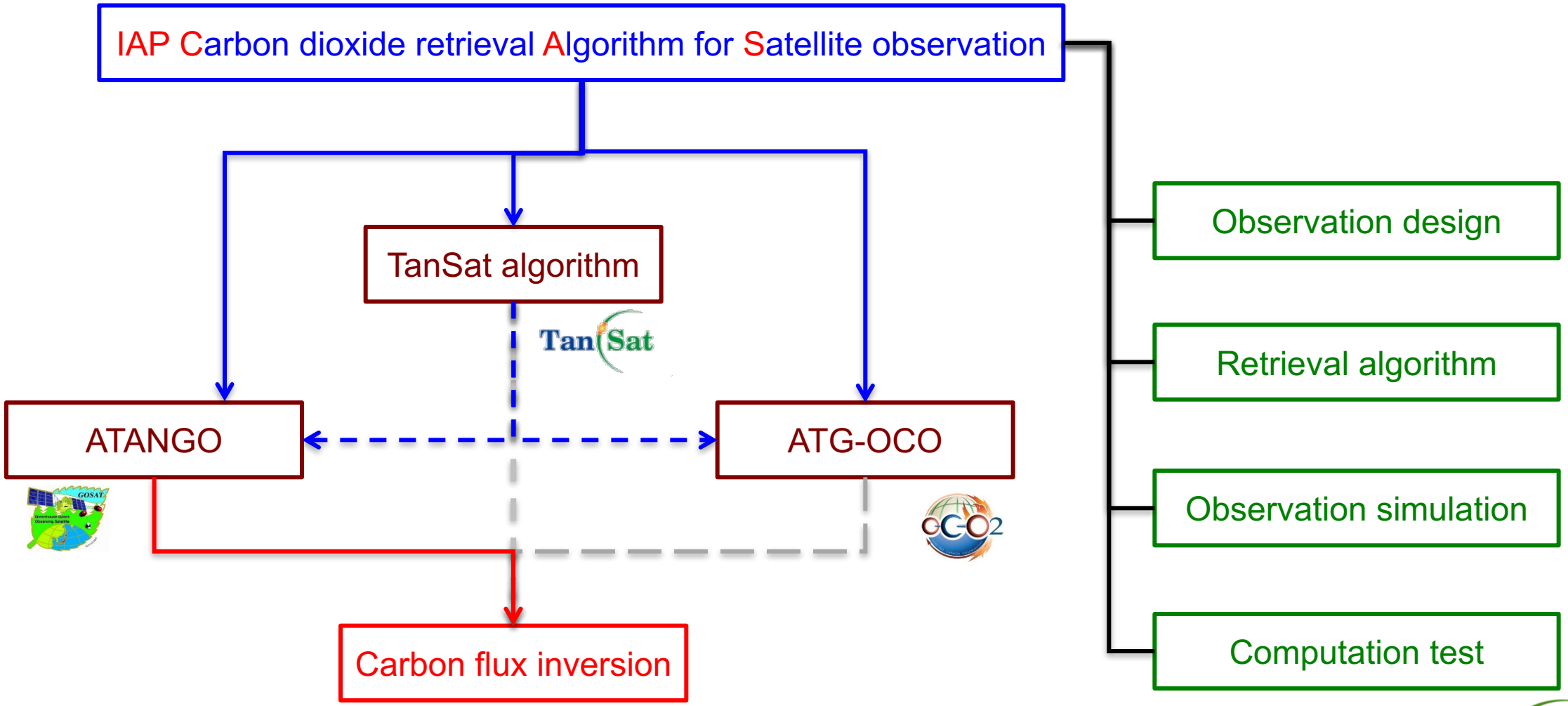
TanSat

TanSat measurement



TanSat

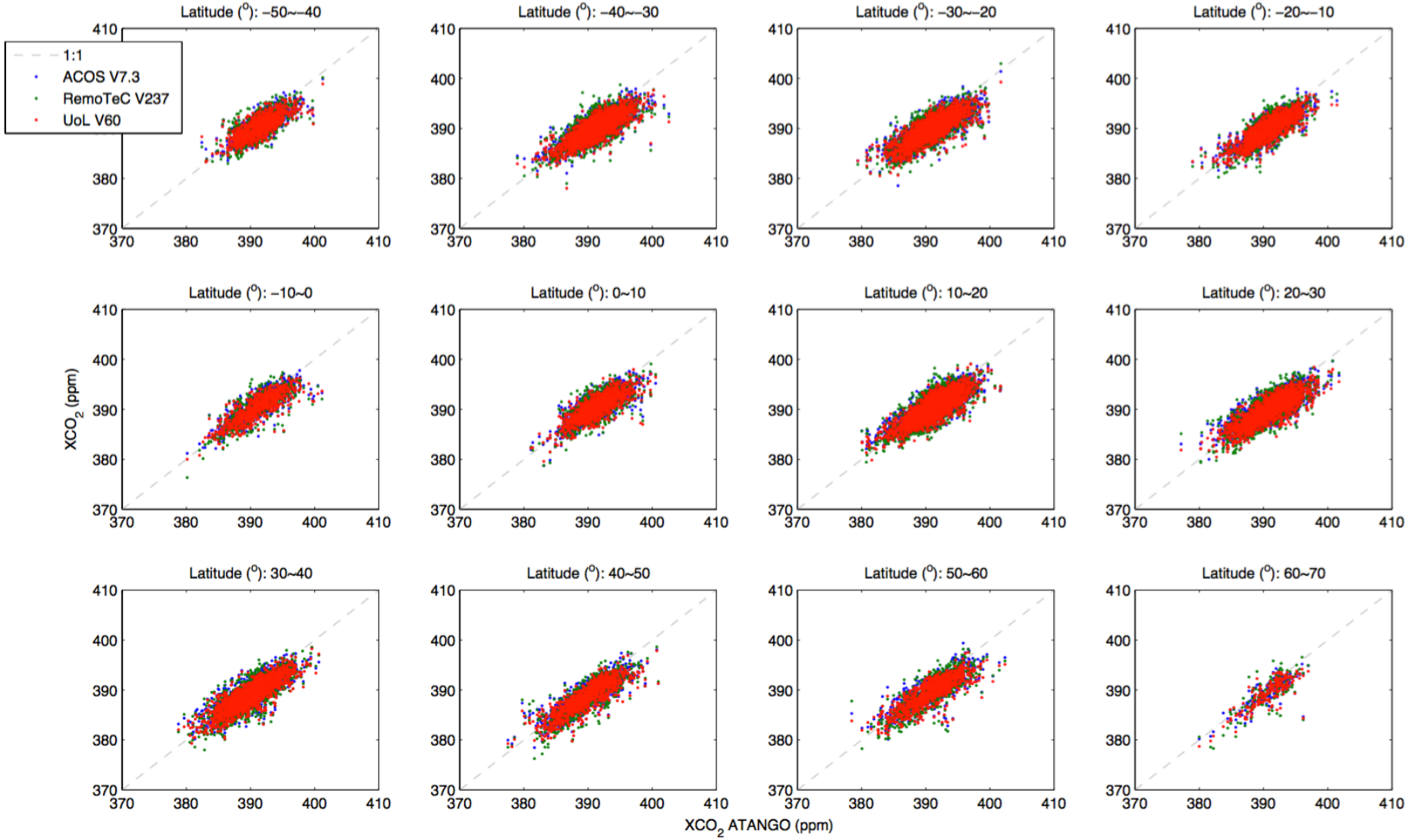
Retrieval algorithm



State Vector

State vector element		Quantity	A priori	A priori error (1σ)	Note
CO_2 profile		21	Climatology model	Climatology model	XCO2 @ each layer boundary
Water vapor scale		1	1.0	0.5	Water vapor profile is from ECMWF
Temperature shift		1	0K	5K	Temperature profile is from ECMWF
Surface pressure		1	ECMWF	4hPa	
Aerosol	Total optical depth	1	Fixed value: 0.05	Fixed value: 5 times	In logarithm
	Profile height	1	Fixed value: 1km	Fixed value: 2km	
	Profile width	1	Fixed value: 1km	Fixed value: 2km	
	Scattering particle size distribution	1	Fixed value: 0.1 um	Fixed value: 5 times	In logarithm
	Absorption particle ratio in optical depth	1	Fixed value: 0.2	Fixed value: 5 times	In logarithm
Cirrus	Total optical depth	1	Fixed value: 0.05	Fixed value: 5 times	In logarithm
	Profile height	1	Fixed value: 9km	Fixed value: 1km	
	Scattering effective radius	1	Fixed value: 30um	Fixed value: 2 times	In logarithm
	Absorption effective radius	1	Fixed value: 30um	Fixed value: 2 times	In logarithm
Albedo		6	Measurement	1.0	Albedo and slope for each band
Wind speed		1	ECMWF	5 m s^{-1}	Glint mode
Dispersion offset		3	Measurement	0.5 cm^{-1}	Only shift in GOSAT
Fluorescence		1	0	0.001 w m^{-2} sr^{-1} cm^{-1}	Shot-cut

GOSAT retrieval: Inter comparison



- 10 degree latitude belt
- consistence in all latitude belt

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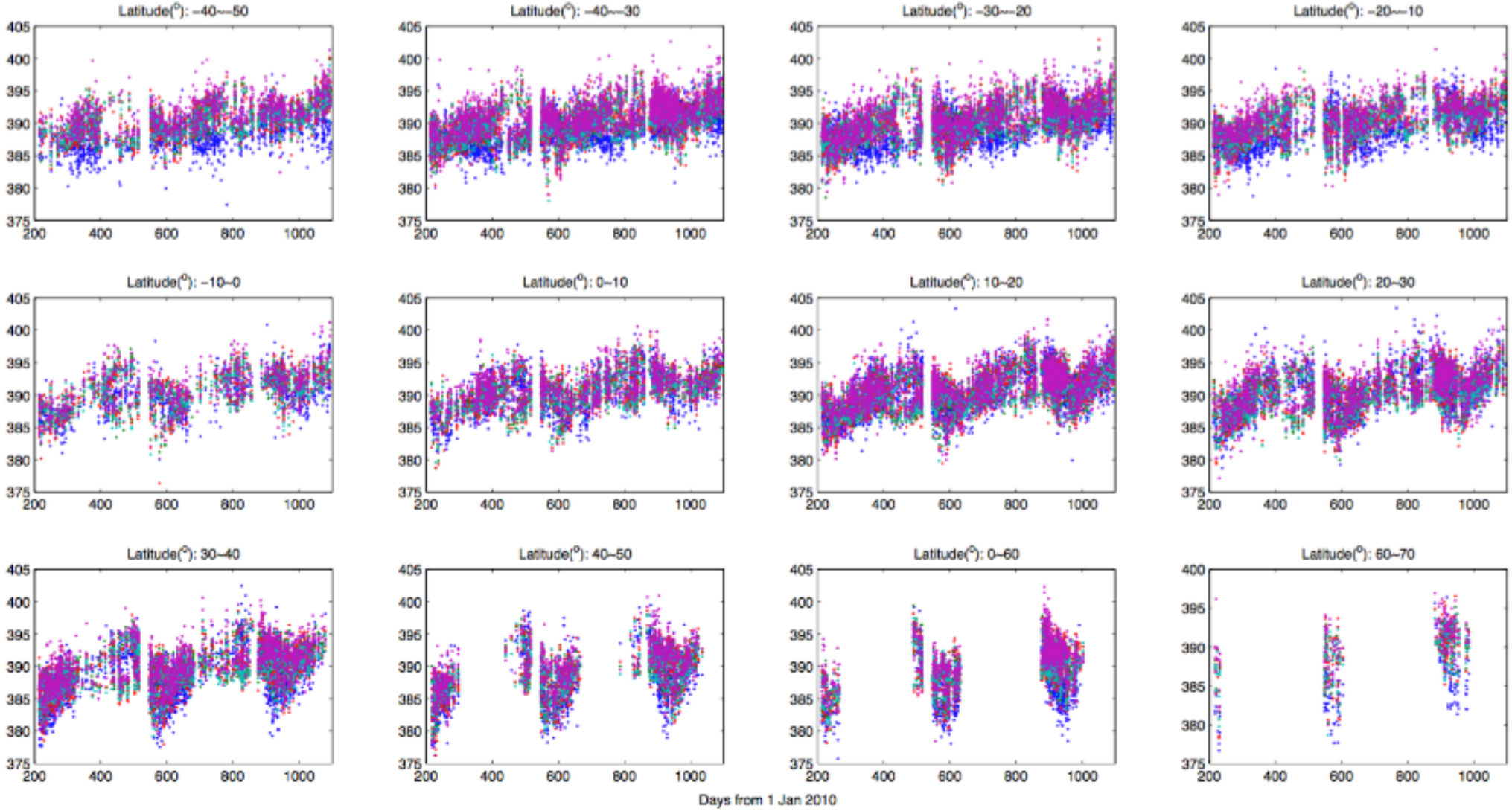
GOSAT retrieval: Inter comparison



- 10 degree latitude belt
- Season variation
- ATANGO agrees well with other algorithm

- NIES–FP V221
- ACOS V7.3
- RemoTeC v237
- UoL V60
- ATANGO V1.3

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GOSAT retrieval: Inter comparison

TCCON site	Retrieval error (accuracy + precision) Before bias correction				
	NIES-FP	ACOS	RemoTeC	UOL-FP	ATANGO
Bialystok	0.04±1.38	1.09±1.75	-2.14±2.53	0.63±1.55	-0.22±2.06
Darwin	-0.96±1.55	-0.17±1.33	-1.38±1.79	1.05±1.74	1.57±2.78
Garmisch	0.62±1.69	2.16±2.54	-1.08±1.54	1.86±2.26	1.40±2.23
Karlsruhe	0.02±1.42	2.41±2.76	-1.31±1.88	1.95±2.30	0.42±1.71
Lamont	-1.46±1.91	-0.76±1.59	-2.81±3.01	0.12±1.05	-0.04±1.60
Lauder	-0.84±1.52	0.43±1.27	-1.89±2.01	1.10±1.60	1.17±1.26
Orleans	-0.28±1.88	1.43±2.07	-1.89±2.62	0.94±1.86	0.37±1.74
ParkFalls	0.58±1.88	1.34±2.12	-1.74±2.18	1.32±1.77	0.61±1.64
Saga	0.41±1.82	-1.34±2.88	-0.63±0.63	2.18±2.68	0.81±2.42
Sodankyla	0.19±1.59	2.80±3.35	-1.05±1.95	1.88±2.18	0.39±2.23
Tuskuba	1.75±2.50	3.52±3.72	0.49±1.40	1.71±2.33	3.71±4.01
Wollongong	-0.90±1.86	0.45±1.30	-1.77±2.28	0.85±1.61	1.18±1.52

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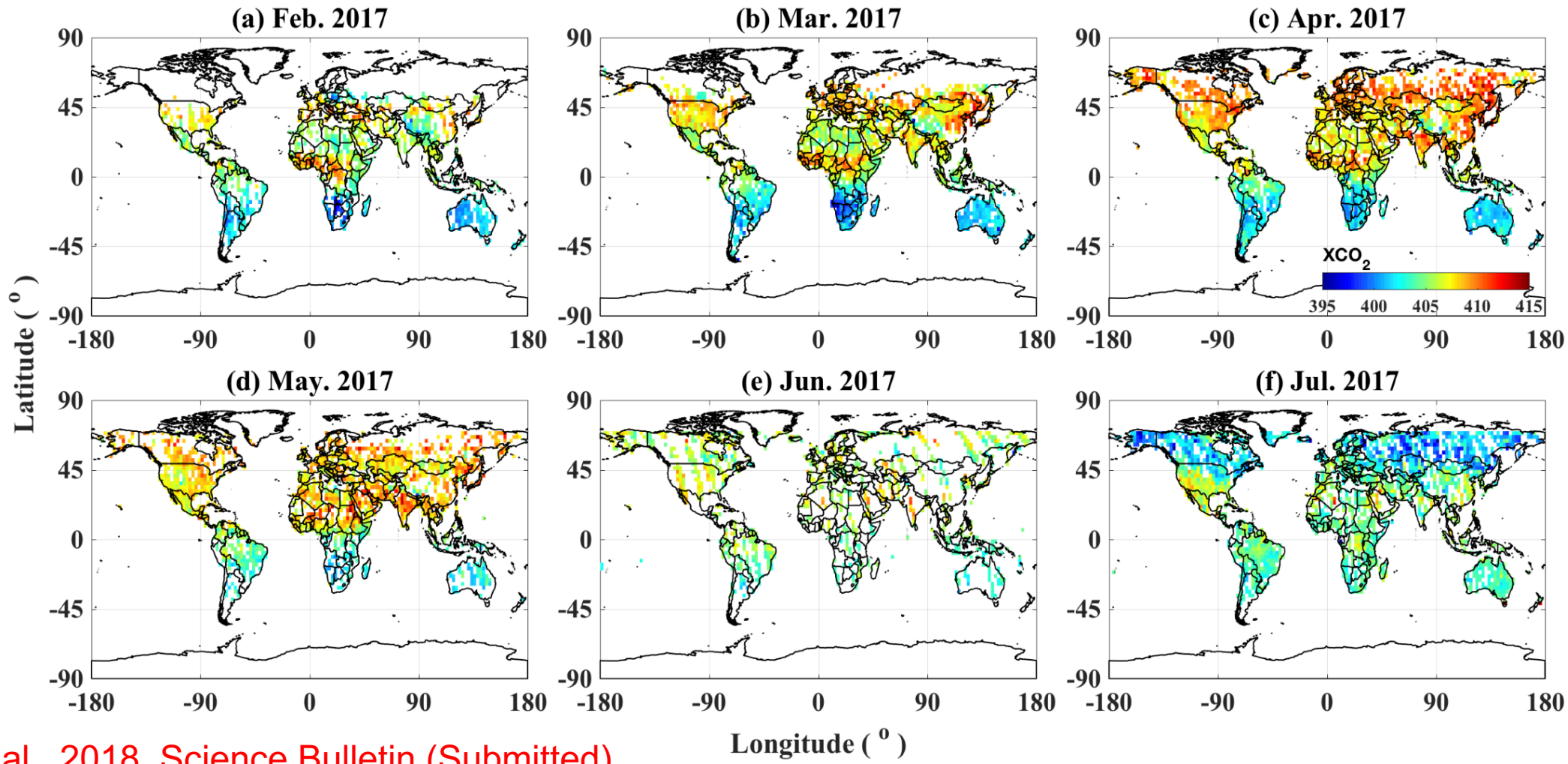
Global distribution of TanSat XCO2



Liu et al., 2018, Science Bulletin (Submitted)

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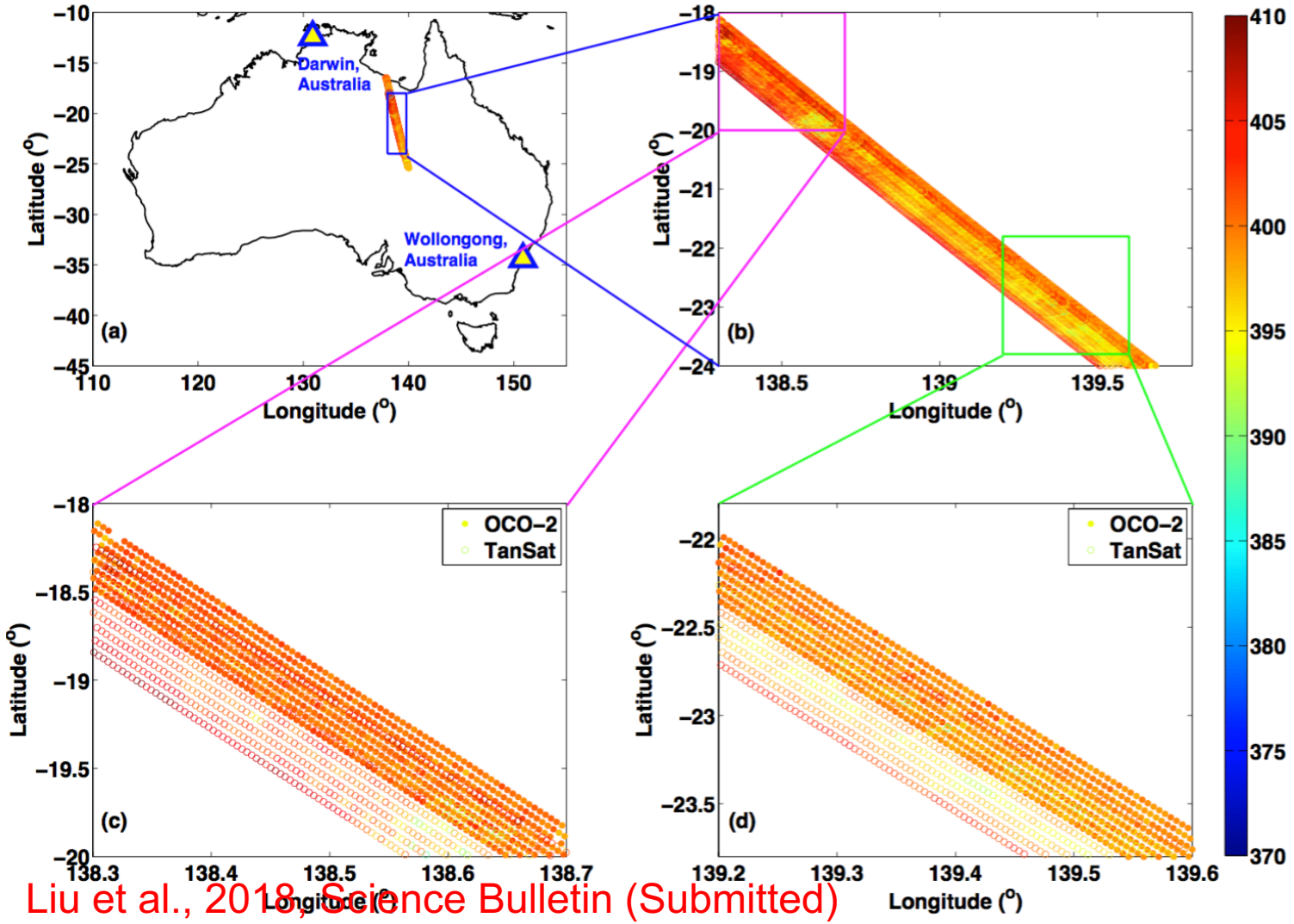
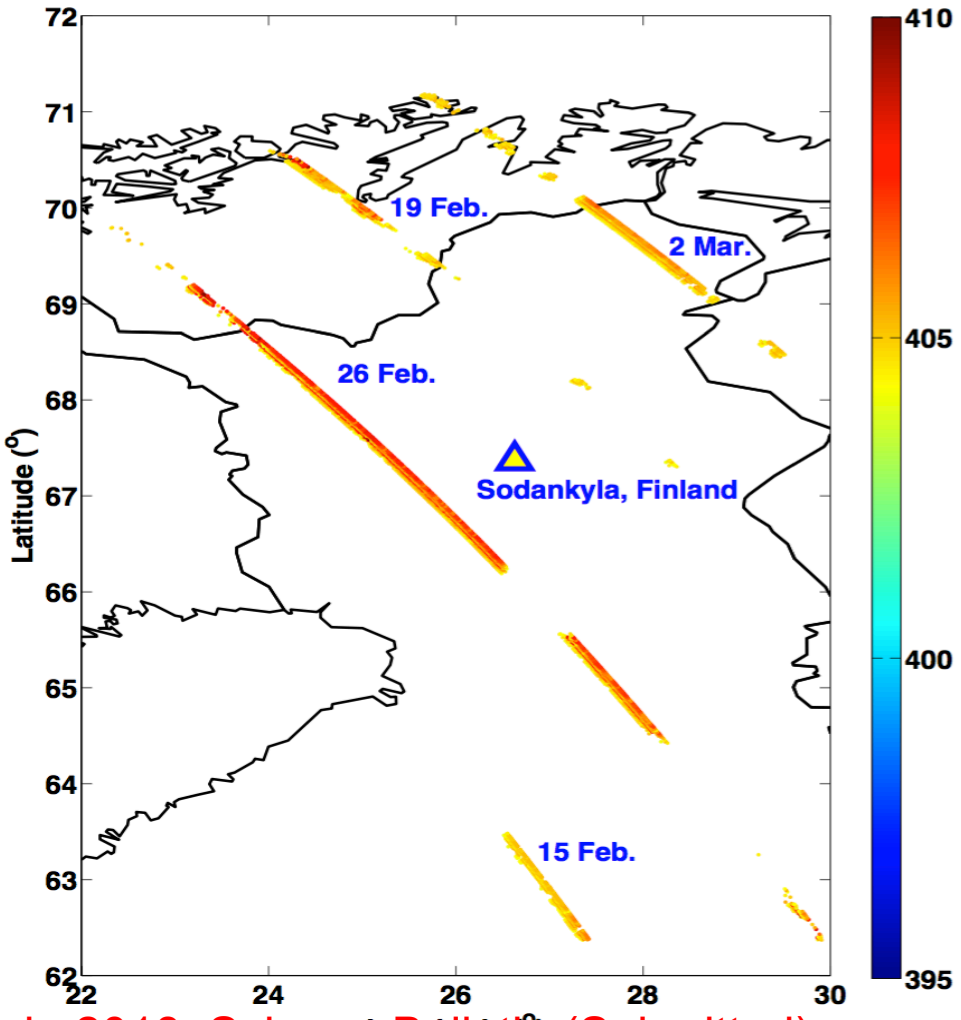
Inter-comparison of TanSat XCO2 with OCO-2



- OCO-2：NO. 14896
- TanSat：NO. 01739
- OCO-2 and TanSat shows a retrieval on a similar level of 395–410 ppm，
- The statistical results of TanSat indicates an average of 400.78 ppm and 397.38 ppm in the north and south sub-region while the OCO-2 is 400.38 ppm and 399.16 ppm.

Liu et al., 2018, Science Bulletin (Submitted)

Validation experiment against TCCON

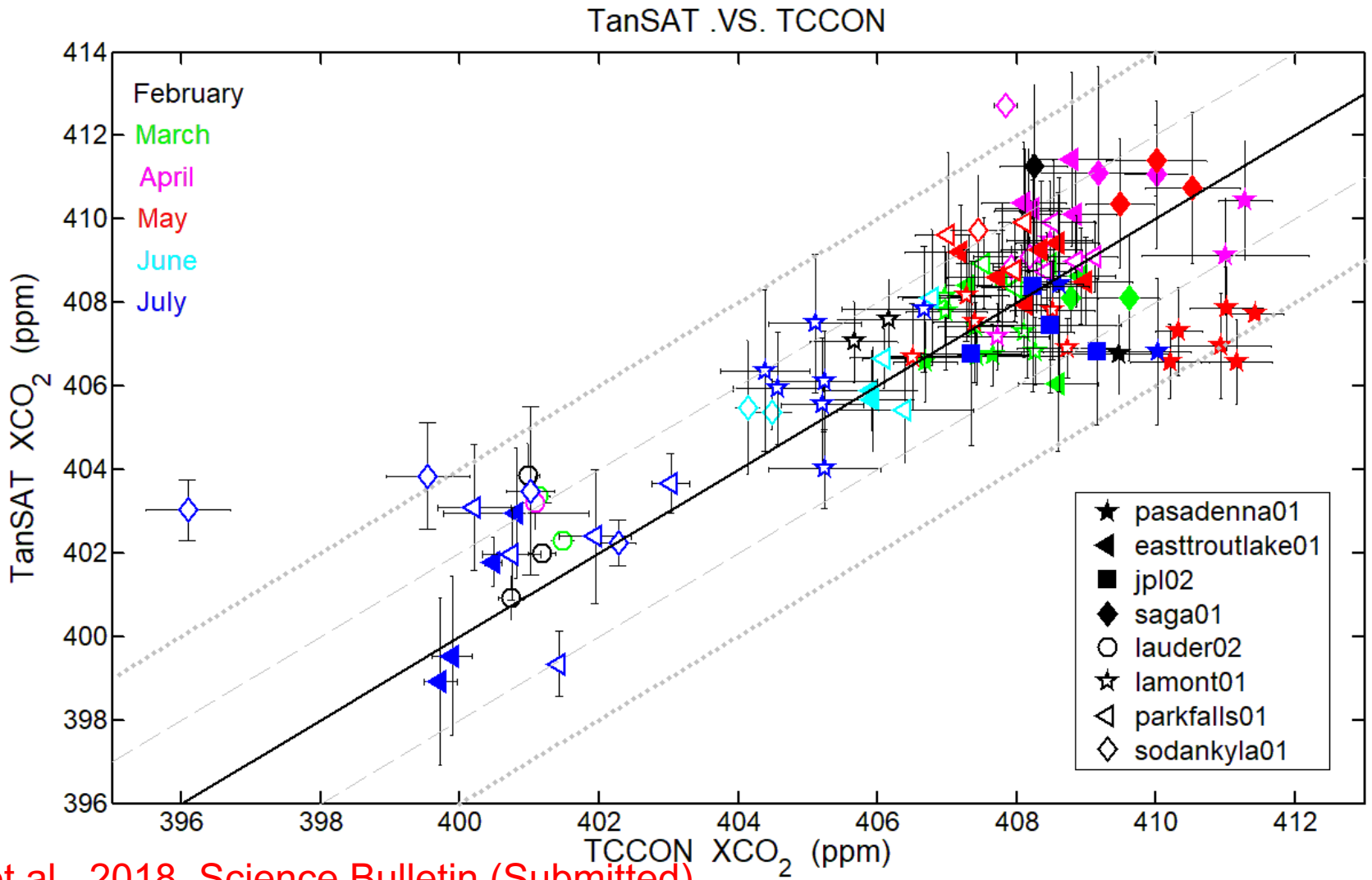


- 550km
- ±2 hours
- 4 orbits (15 Feb., 19 Feb., 26 Feb. and 2 Mar)
- not seriously contaminated by the cloud
- The statistic indicates an average of 405.43 ppm from TanSat measurements and 407.62 ppm for TCCON observations.

Liu et al., 2018, Science Bulletin (Submitted)

TanSat

Validation of TanSat XCO2 with TCCON



- 8 TCCON sites
- 6 months
- 550km，±1hour
- Bias
  - almost <4 ppm
- Precision
  - 1~3 ppm
- seasonal variation
  - March
  - July

Liu et al., 2018, Science Bulletin (Submitted)

TanSat

Validation of TanSat XCO2 with TCCON

Site	Longitude	Latitude	Precision (ppm)					
			February	March	April	May	June	July
Pasadena, CA	-118.13	34.14	2.71	0.71	1.46	3.71	--	2.27
East Trout Lake, Canada	-104.99	54.36	--	1.61	2.12	1.05	0.18	1.33
Saga, Japan	130.29	33.24	2.57	1.71	1.56	0.96	--	--
Lauder, New Zealand	169.68	-45.04	1.74	1.69	2.12	--	--	--
Lamont, OK, USA	-97.49	36.60	1.41	0.98	0.81	0.97	--	1.48
Park Falls, WI, USA	-90.27	45.94	--	0.78	0.72	1.88	1.01	1.72
Sodankyla, Finland	26.63	67.37	--	--	2.92	2.29	1.15	4.27
JPL	-118.18	34.20	--	--	--	--	--	1.30
Average			2.11	1.25	1.67	1.81	0.78	2.06

- **8 TCCON sites, 6 months, screening condition：550km & ±1hour**

Liu et al., 2018, Science Bulletin (Submitted)

TanSat

SIF retrieval method

$$\vec{f}\left(F_s^{rel}, a\right) = \log\left(< \vec{I}_0 + F_s^{rel} >\right) + \sum_{i=0}^{n} a_i \cdot \lambda^i,$$

(Frankenberg et al., 2011)

$$F = F^{rel} \cdot I_{cont}$$

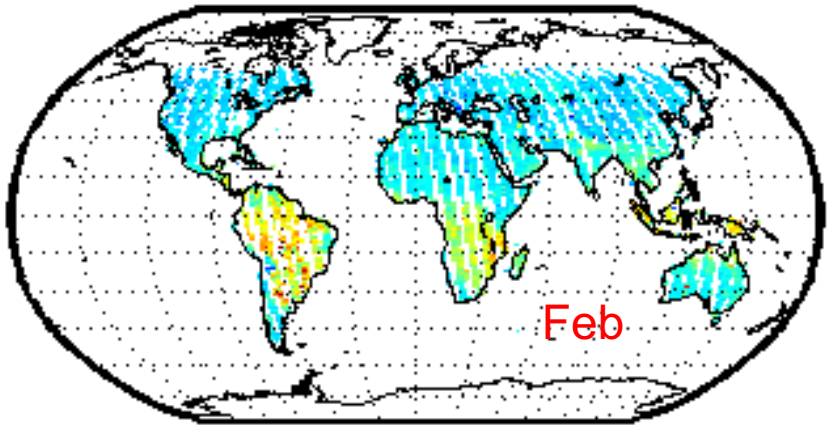
- **Wavenumber: 12982~12988 cm-1**
- **A low-order polynomial to approximate the scattering and surface reflection terms**

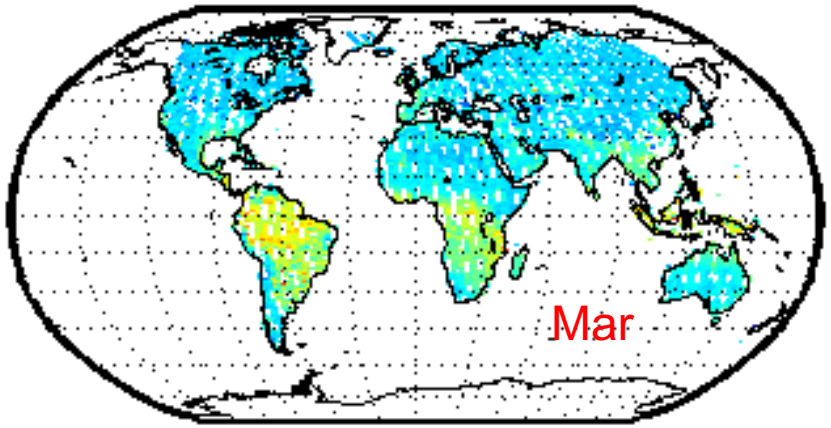
State vector element	note
Relative SIF	Relative contribution of SIF to continuum
OD scale	Scale of O2 absorption
polynomial coefficient	Coefficient of the low-order polynomial
Wavenumber shift	Wavenumber shift caused by instrument movement

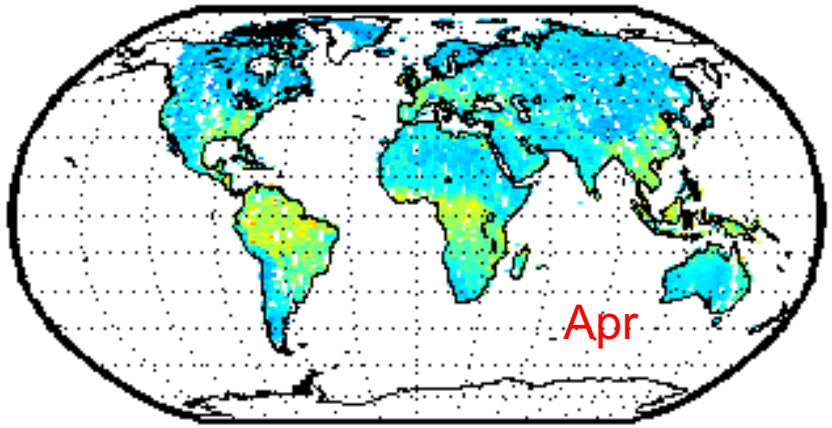
TanSat

Retrieval test with OCO-2

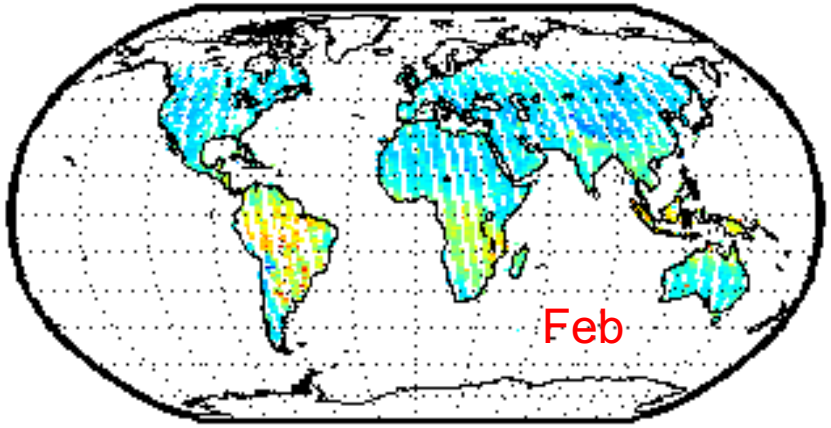
SIF from sif_atango, after bias correction

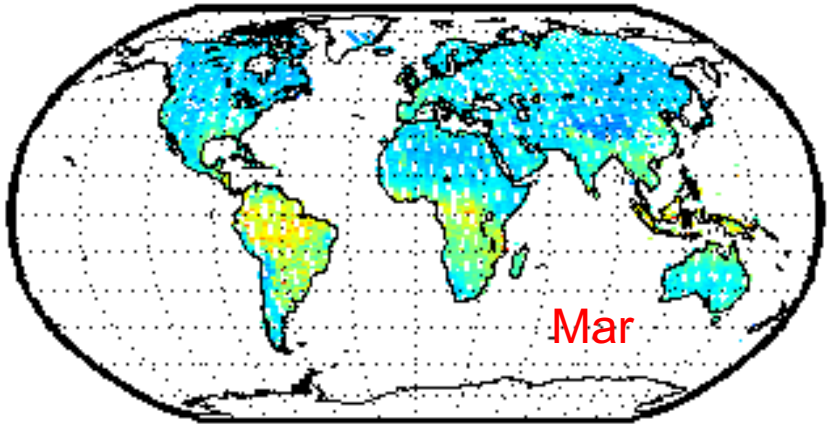


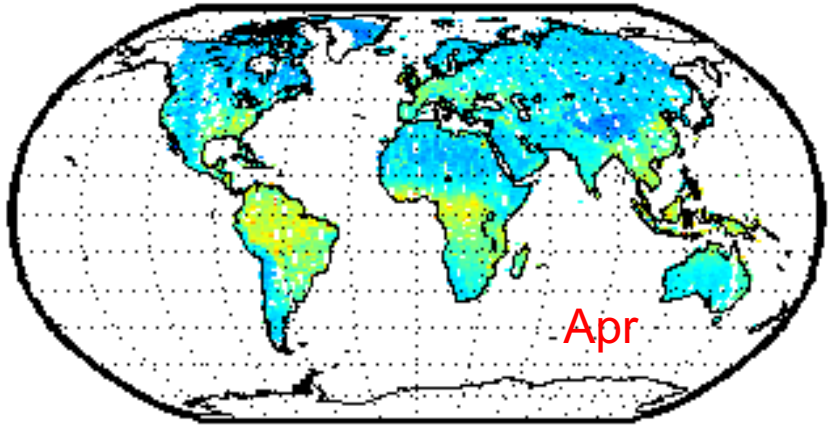


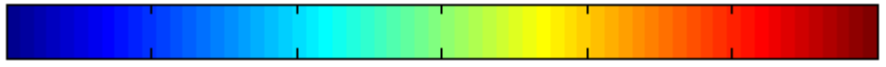


SIF from OCO2 Lite L2, after bias correction





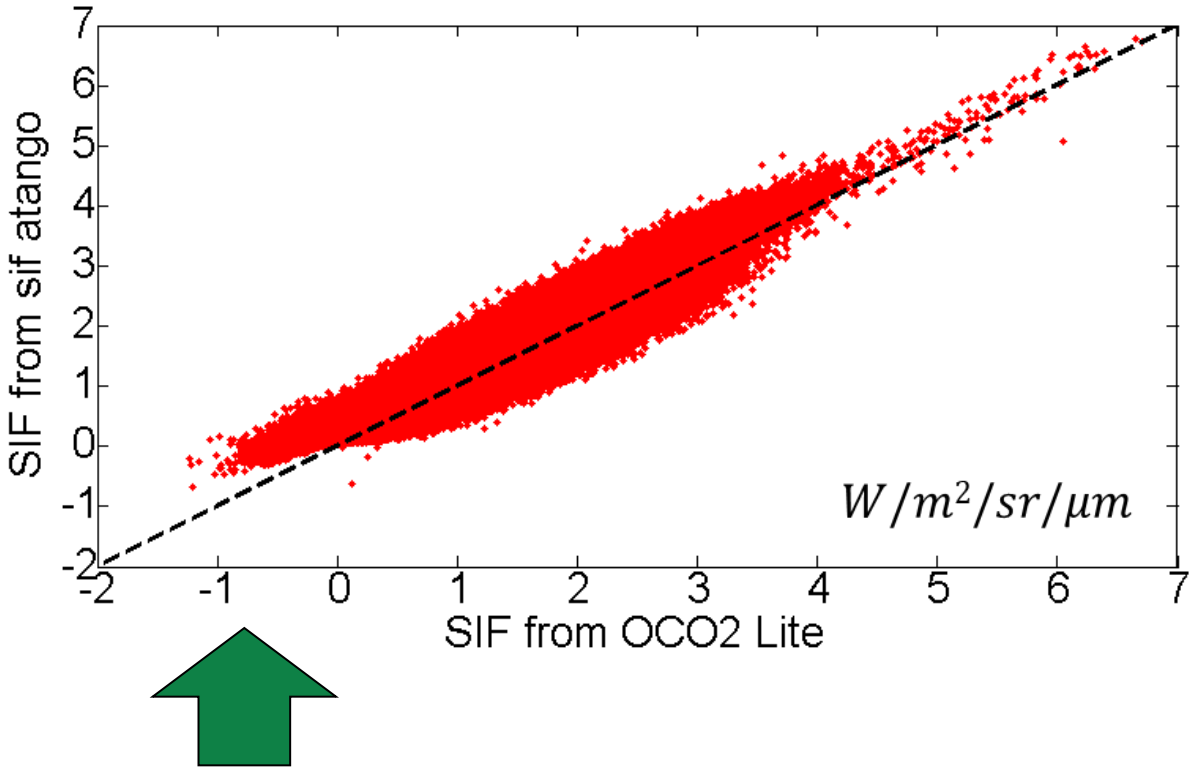




$W/m^2/sr/\mu m$

TanSat

Retrieval test with OCO-2

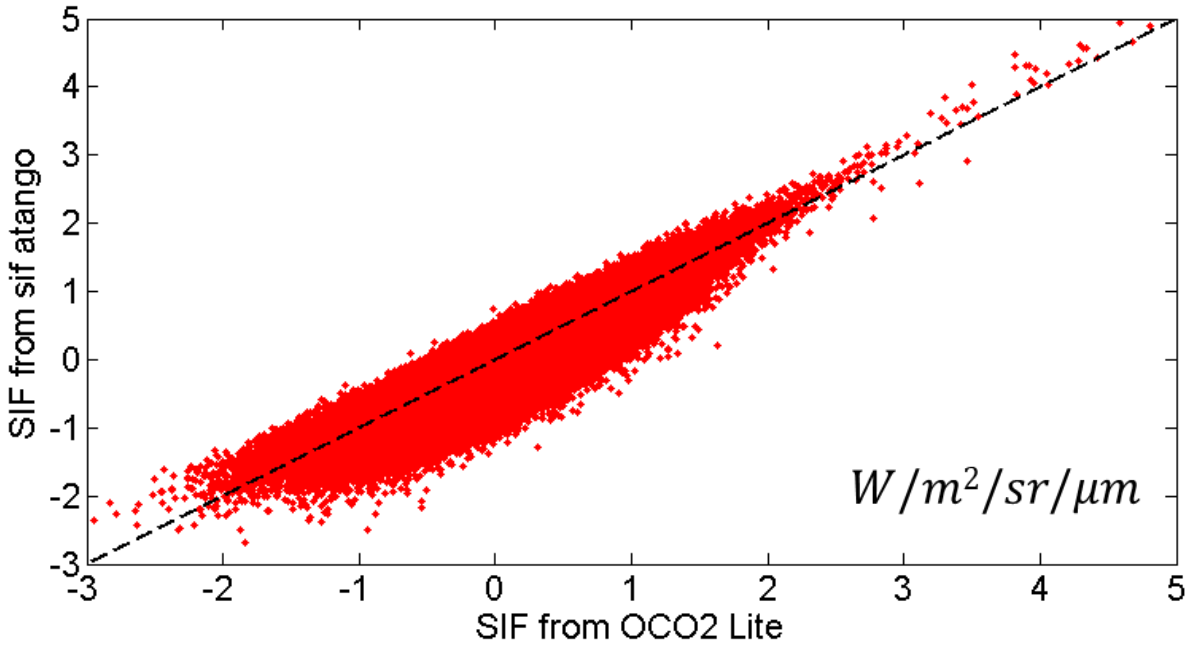


Before bias correction

Scatter plot inter comparison

- **3 months for scatter plot**
  - **Feb, Mar, Apr**

After bias correction



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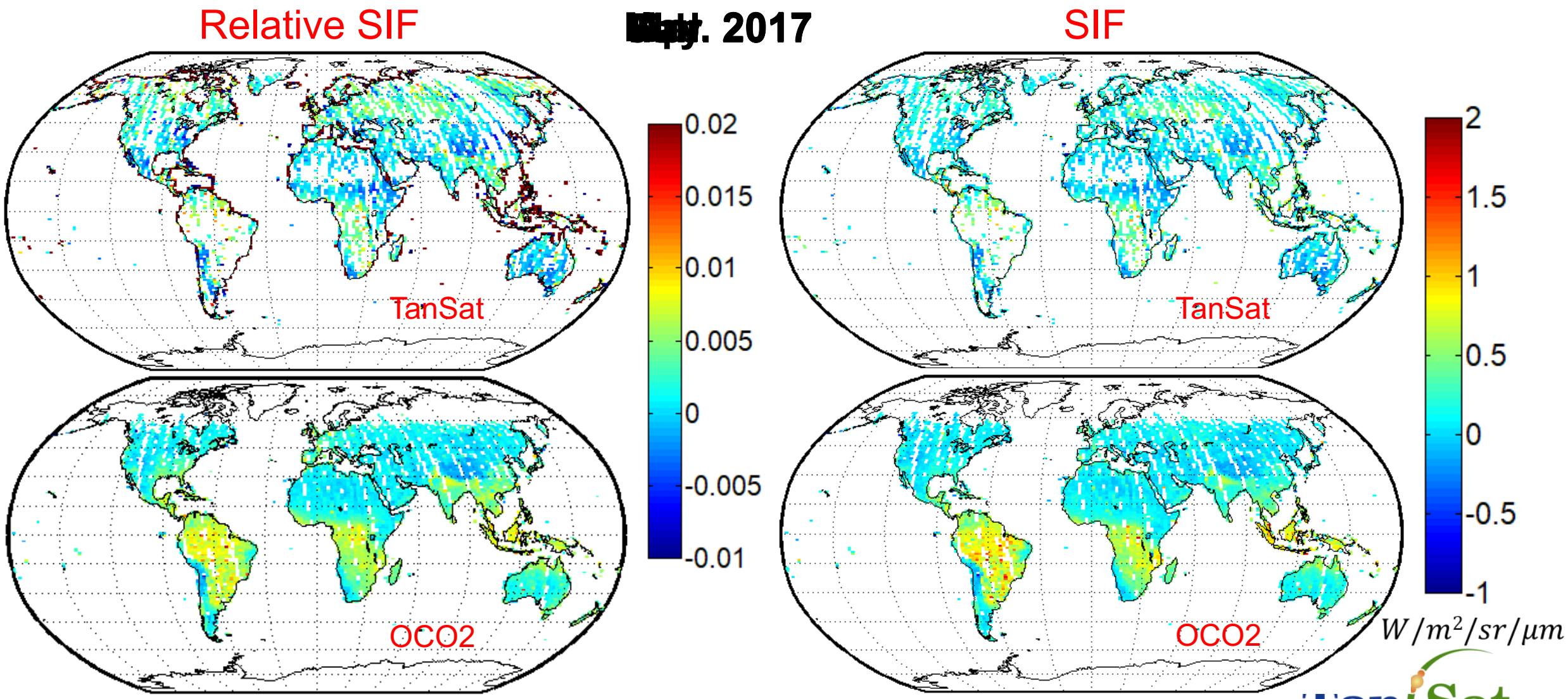
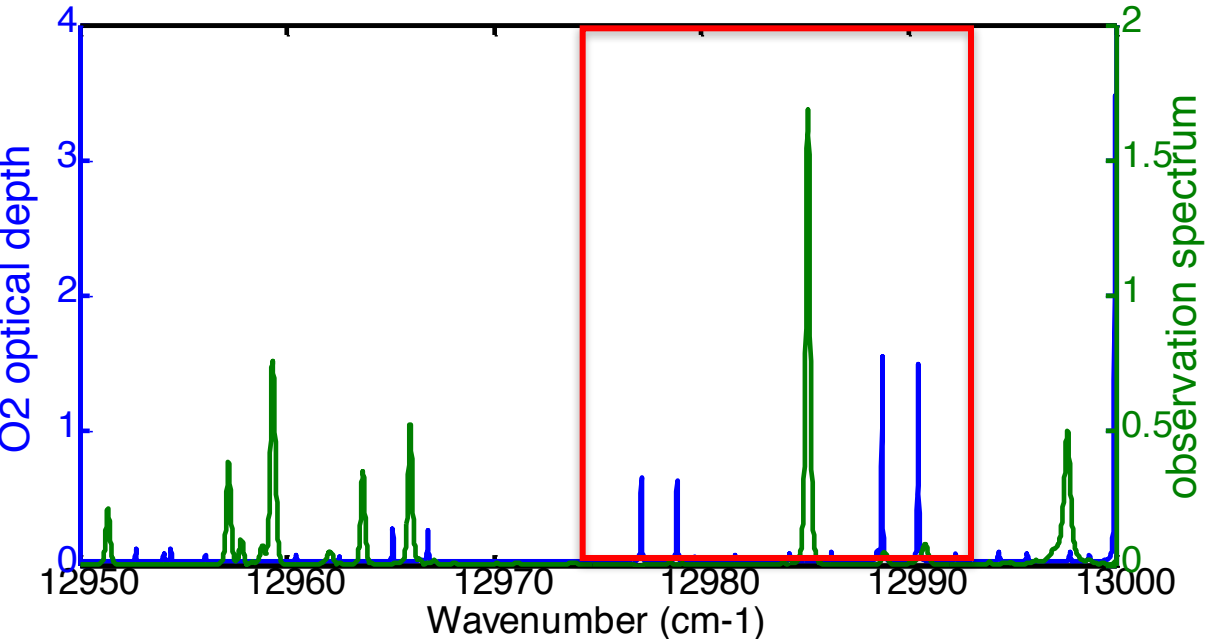
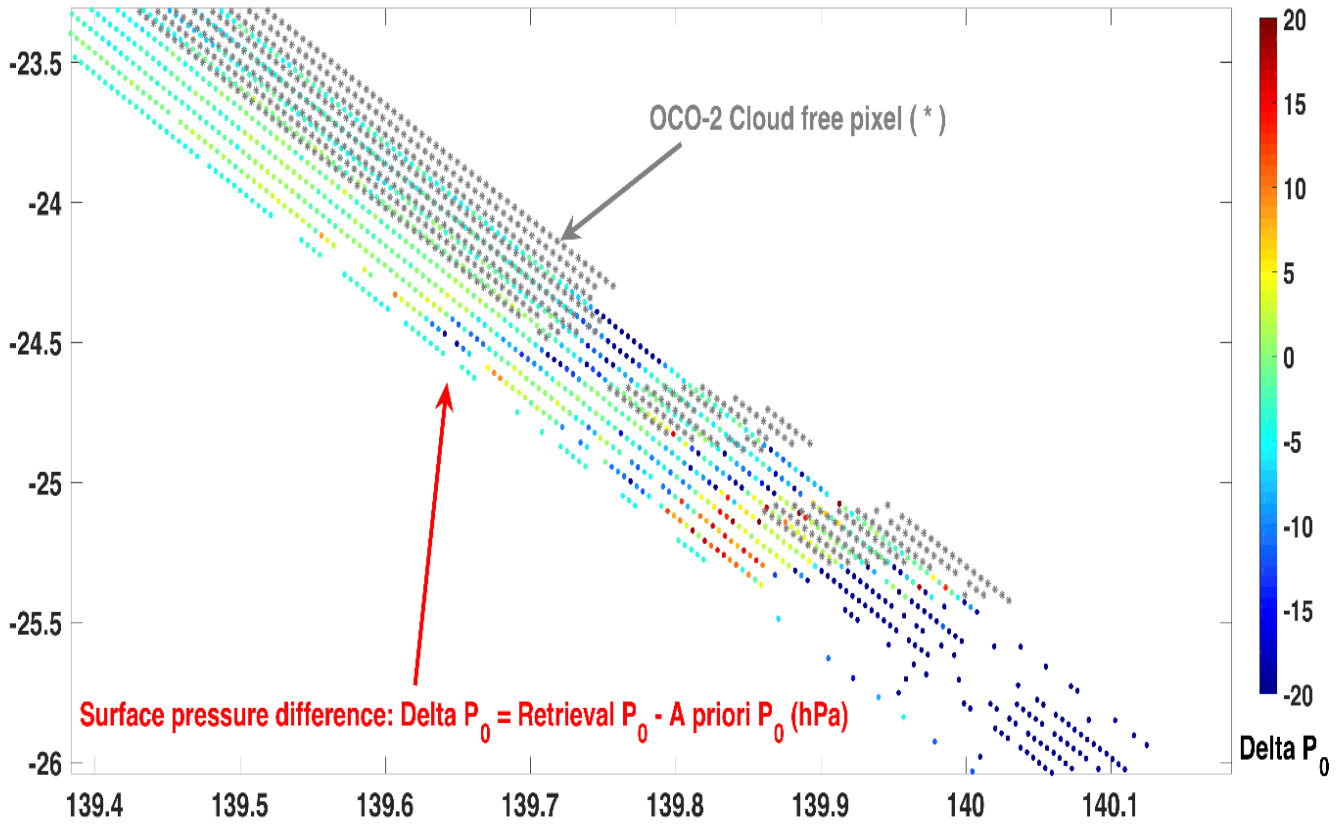
Inter comparison: SIF from TanSat & OCO-2



TanSat

Case of Cloud Screening test

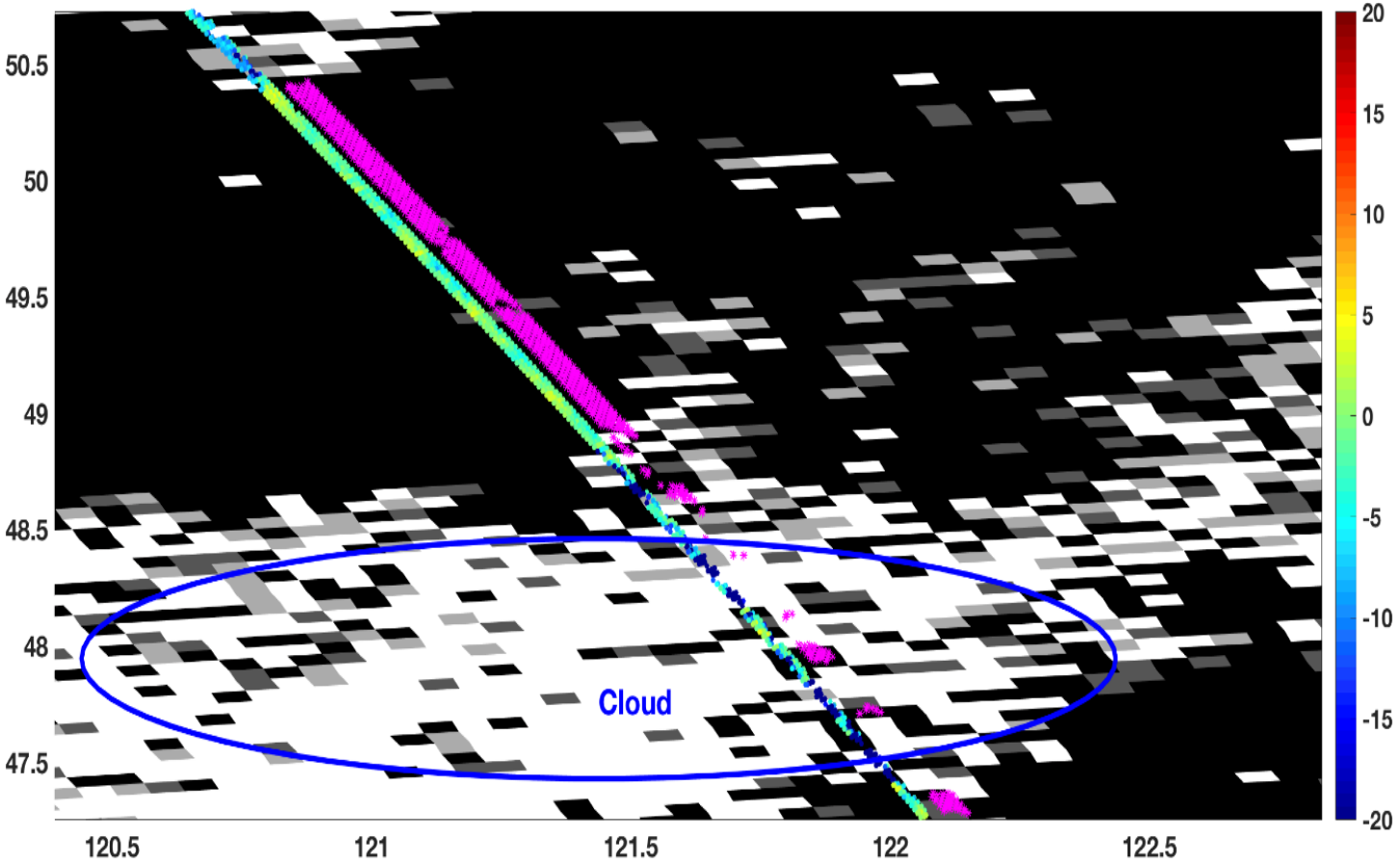


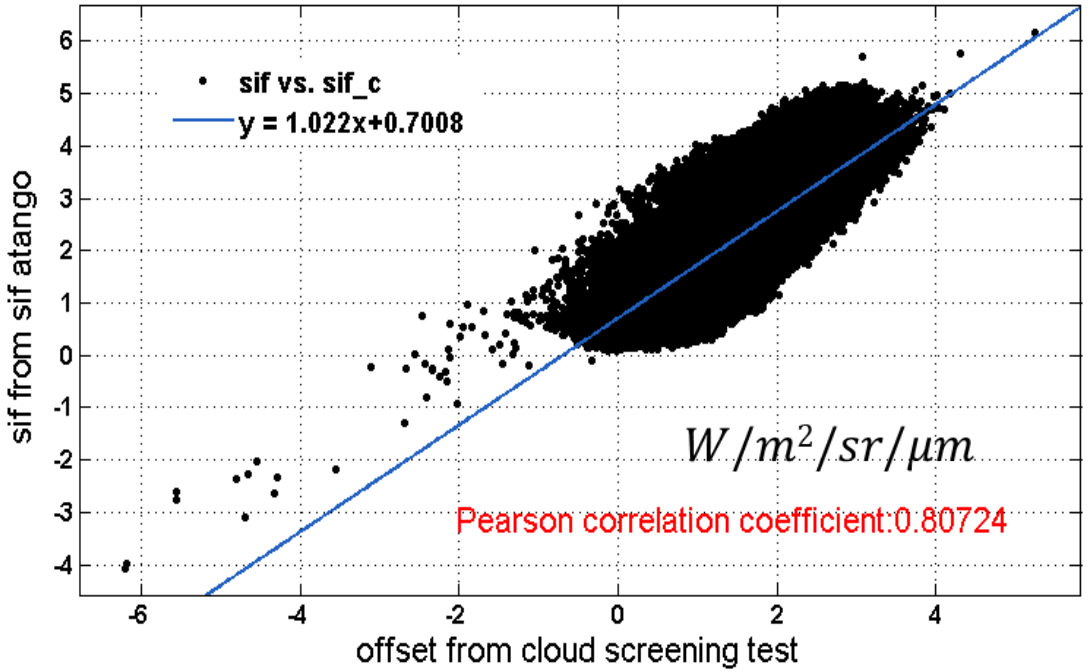


- **Wavenumber : 12950-12970 cm-1**
- **Cover a Fraunhofer line**
- **Abs(Δp) < 20**

TanSat

Case of Cloud Screening test





- **Strong correlation between offset from cloud screening and sif**

TanSat

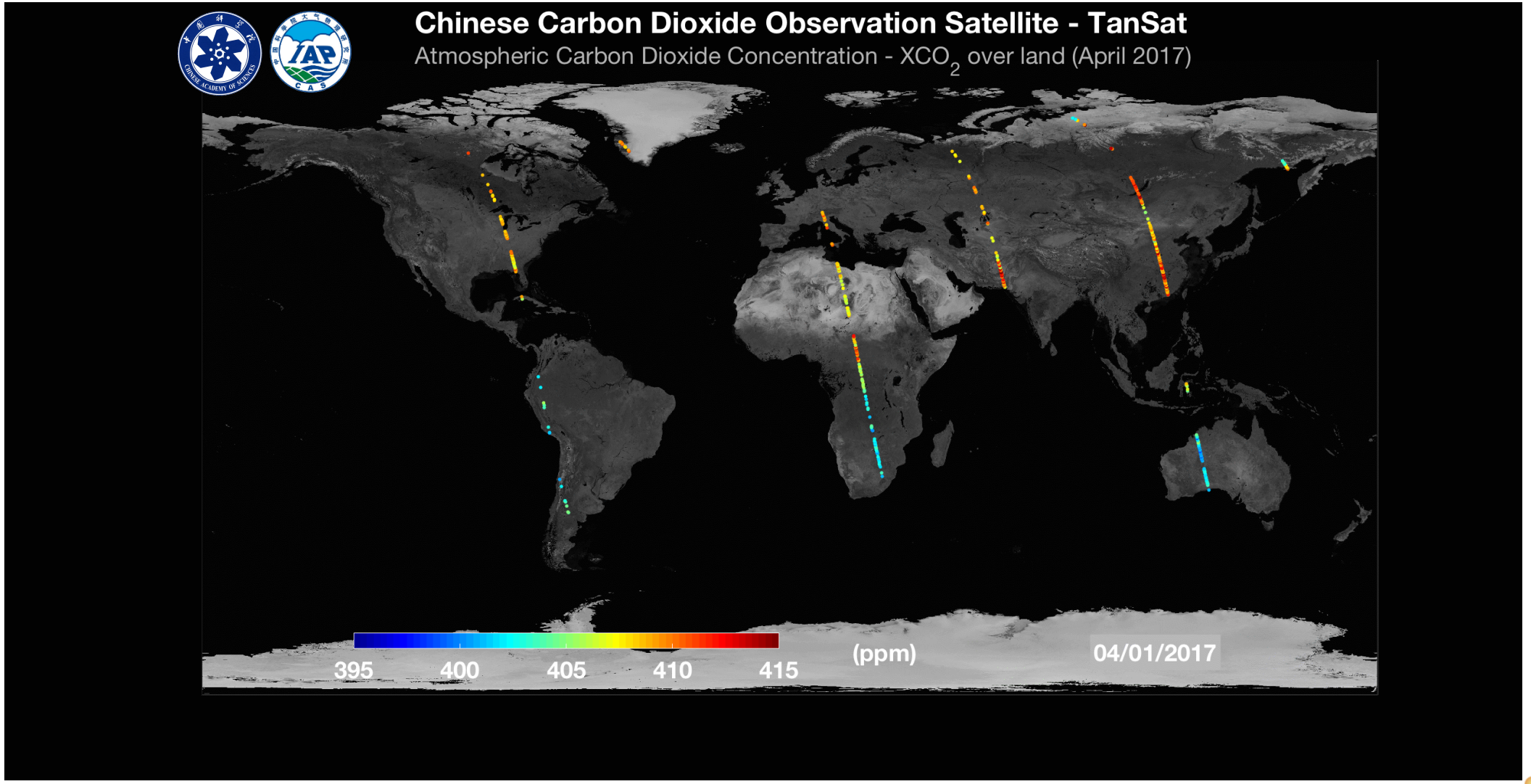
Summary

1. The inter comparison study between ATANGO and NIES-FP, ACOS, UoL and RemoTeC has been carried out.

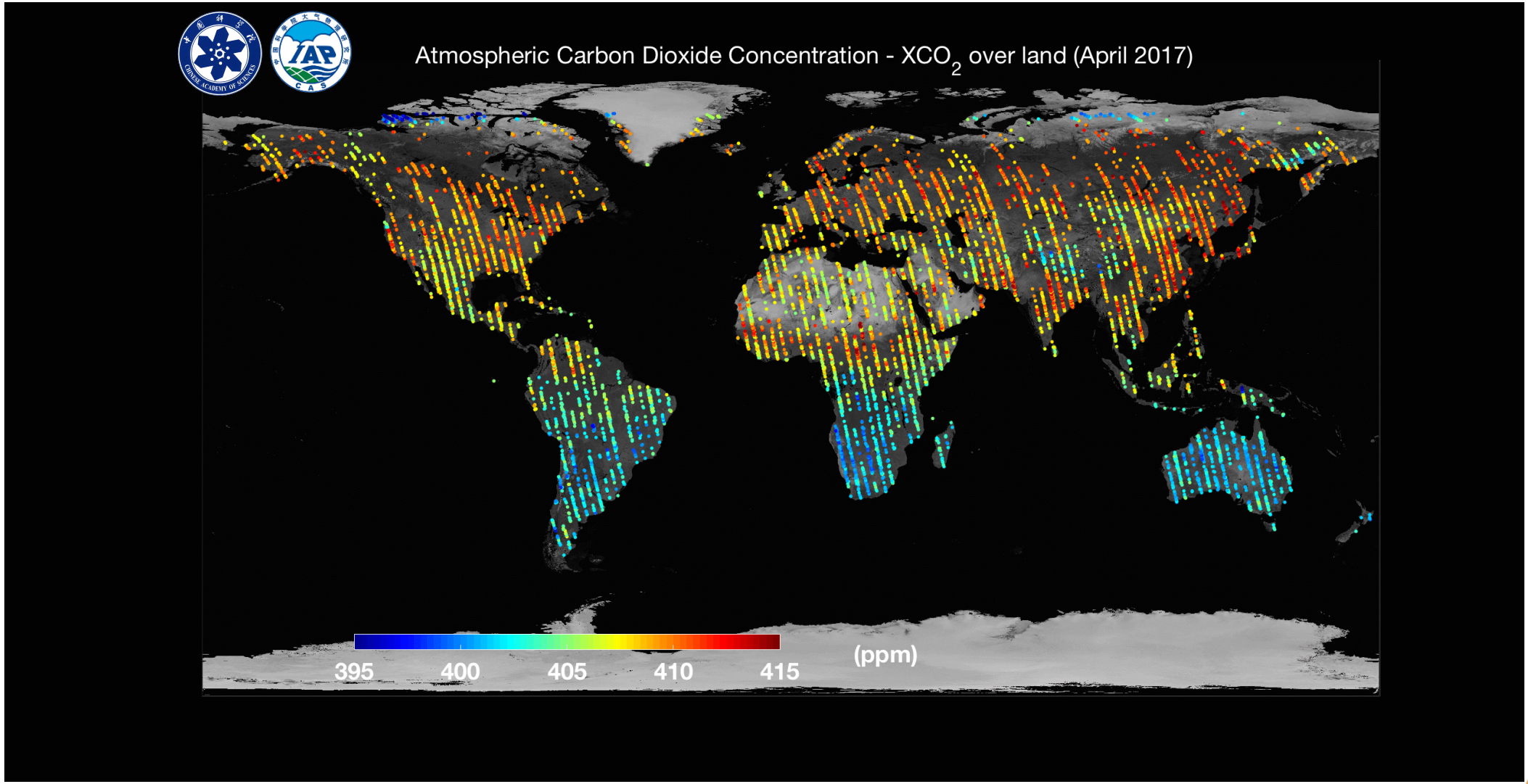
2. Retrieval of sif from TanSat measurements and the inter comparison of TanSat sif with OCO2 products has been completed.

3. TanSat preliminary retrieval and validation of XCO2 has been studied and more retrieval work will be continued in future.

TanSat: XCO2_April



TanSat & OCO-2: XCO2_April



Acknowledgements

We would like to thank GOSAT and OCO-2 program and TCCON for providing the observation data. And we also would like to thank ACOS, GOSAT, RemoTeC and UoL scientific research team for the valuable suggestion and recommendation.

TanSat

Thanks for your attention !

supply

Tansat bias function