Orbiting Carbon Observatory-2

XCO2 retrieval from OCO-2 satellite observations using RemoTeC

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RemoTeC

- **For OCO-2**

  Vector radiative transfer model **LINTRAN V 2.0**

  Aerosol scattering for ocean glint retrievals

- **Retrieval state vector**

  CO_2 sub-columns (12 layers), H_2O total column, Aerosol parameters

  Surface albedo, Spectral properties

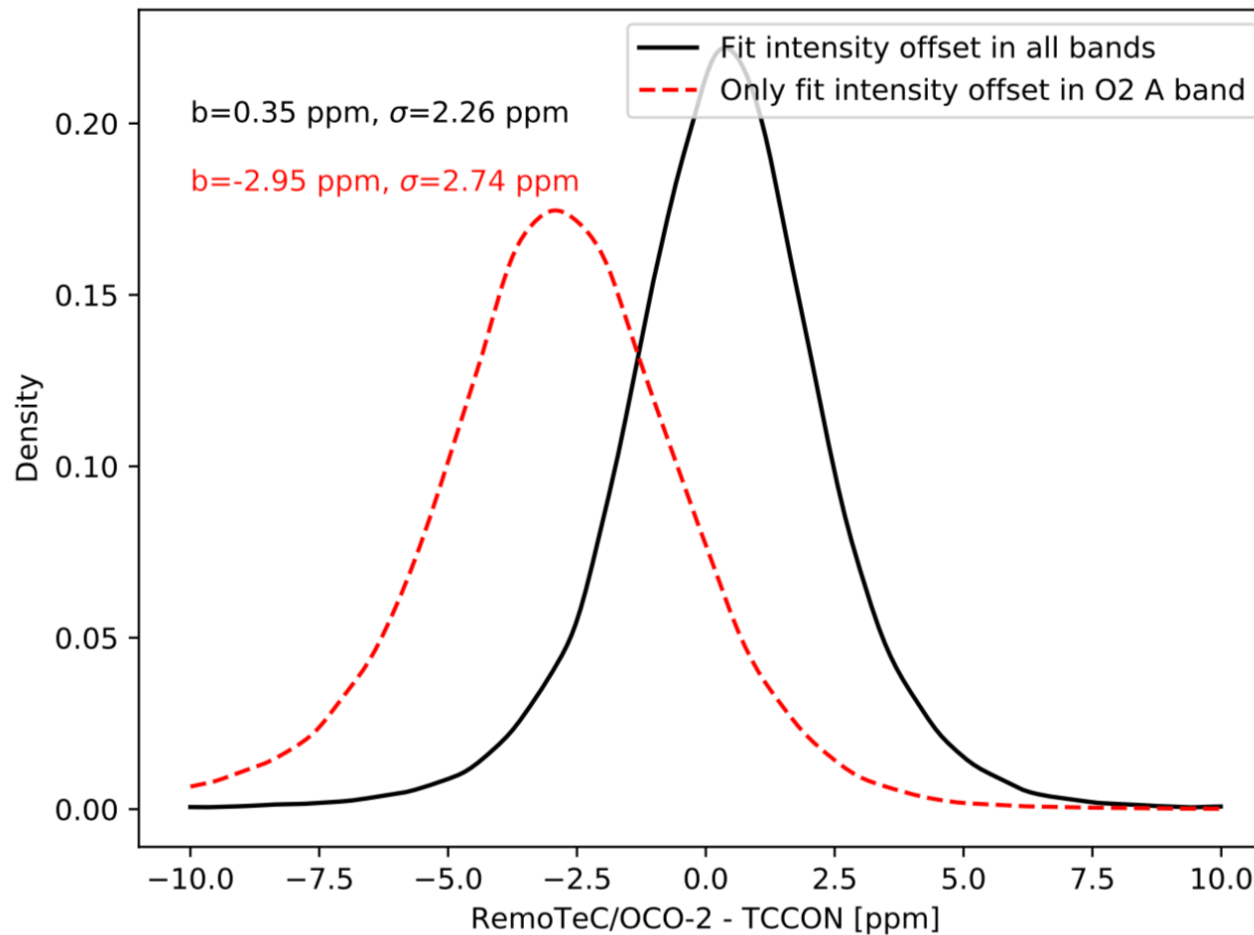- **OCO-2 Data and Cloud screening**

  Time period: September, 2014 – July, 2016

  No-scattering retrieval: **30%** of total soundings are classified as cloud-free cases
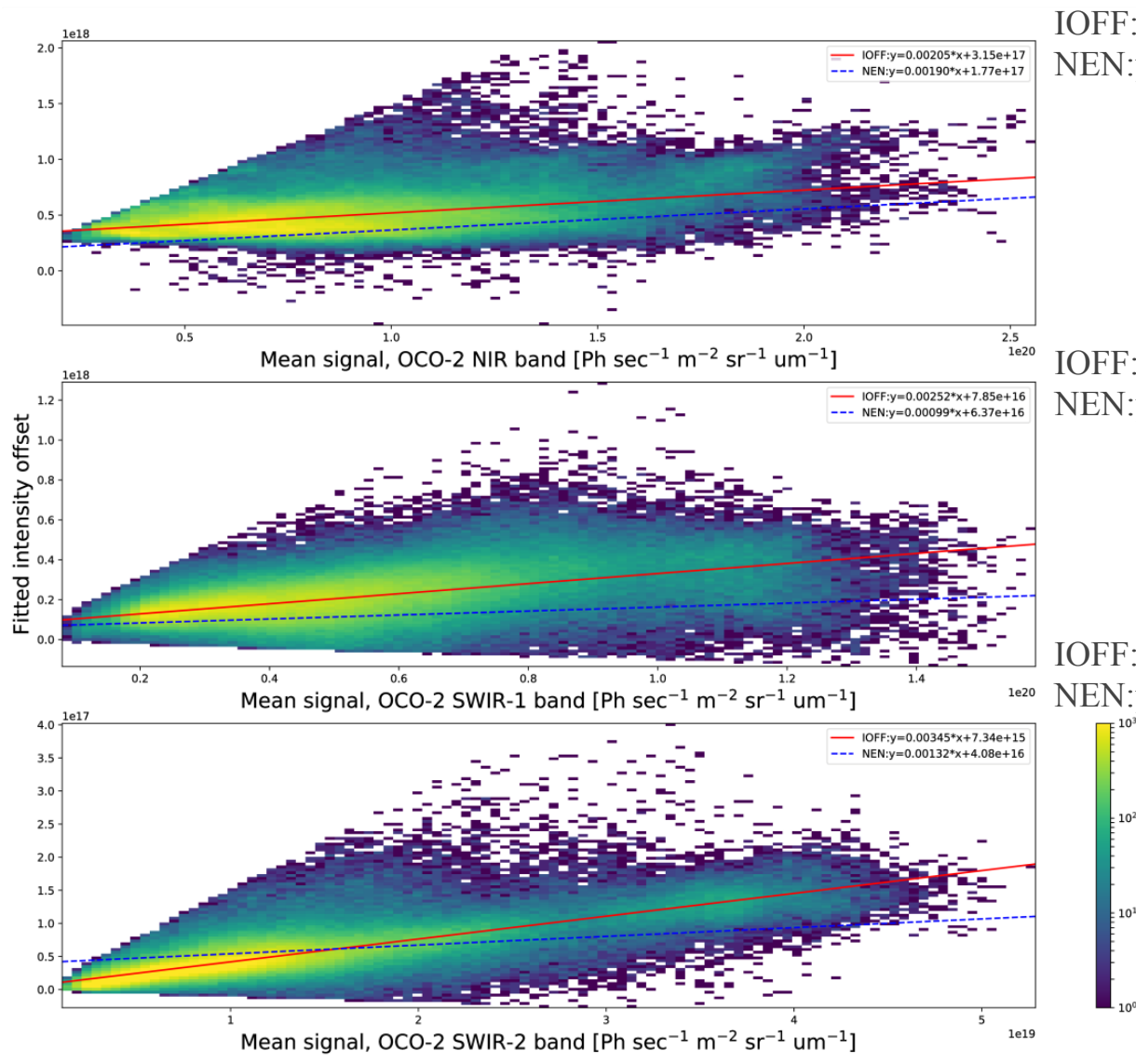
- **Fit residual**

   Fit residual generally less than **1%**.

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Importance of intensity offset

Bias increased by 2.5 ppm. Std increased by 0.5 ppm

Amount of intensity offset

IOFF:y=**0.00205x**+3.15*10^17
NEN:y=0.00190x+1.77*10^17

IOFF:y=**0.00252x**+7.85*10^16
NEN:y=0.00099x+6.37*10^16

IOFF:y=**0.00345x**+7.34*10^15
NEN:y=0.00132x+4.08*10^16

TCCON validation

- 20 TCCON sites

- Sodankyla, Finland (67.3N, 26.6E) Bialystok, Poland (53.2N, 23.0E) Bremen, Germany (53.1N, 8.8E) Karlsruhe, Germany(49.1N,8.4E) ParkFalls,WI(USA)(48.4N,2.3E),Paris,France(48.4N,2.3E),Izana,Tenerife(48.4N,2.3E)Orleans, France (47.9N, 2.1E) Garmisch, Germany (47.4N, 11.0E) Rikubetse, Japan(43.4N, 143.7E) Lamont, OK(USA) (36.6N, 97.4W) Anmyeondo, Korea (36.5N, 126.3E) Tsukuba, Japan (36.0N, 140.1E) Dryden, USA (34.9N, 117.8W)Saga, Japan (33.2N, 130.2E) Ascension, Island (7.9165S, 14.3325W) Darwin, Australia (12.4S, 130.9E) Reunion, Island (20.901S, 55.485E) Wollongong, Australia (34.4S, 150.8E) Lauder, New Zealand (45.0S, 169.6E)

- Collocation

- Less than **5 degrees** in both latitude and longitude.

- Time difference less than **2 hours**.

Bias correction

- **Footprint biases**
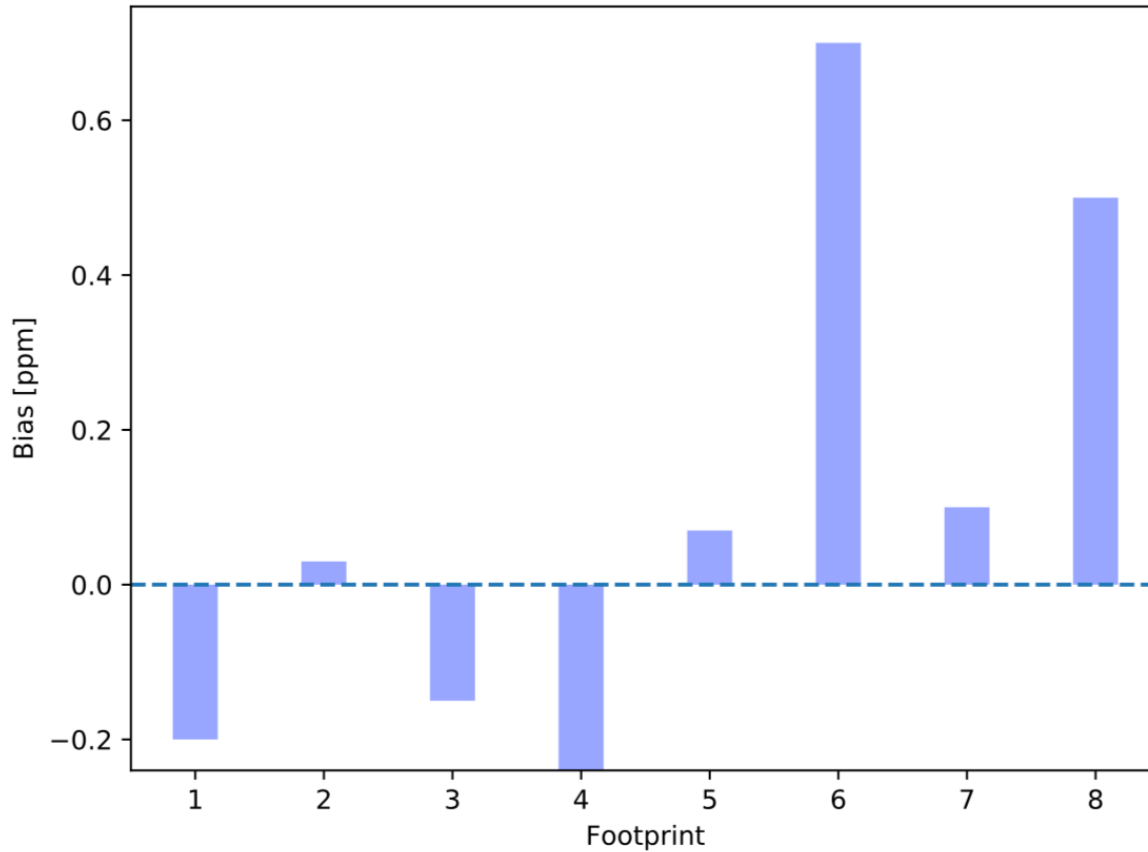
Std = 0.3 ppm

We use target mode observations when all 8 footprints in one frame converged.

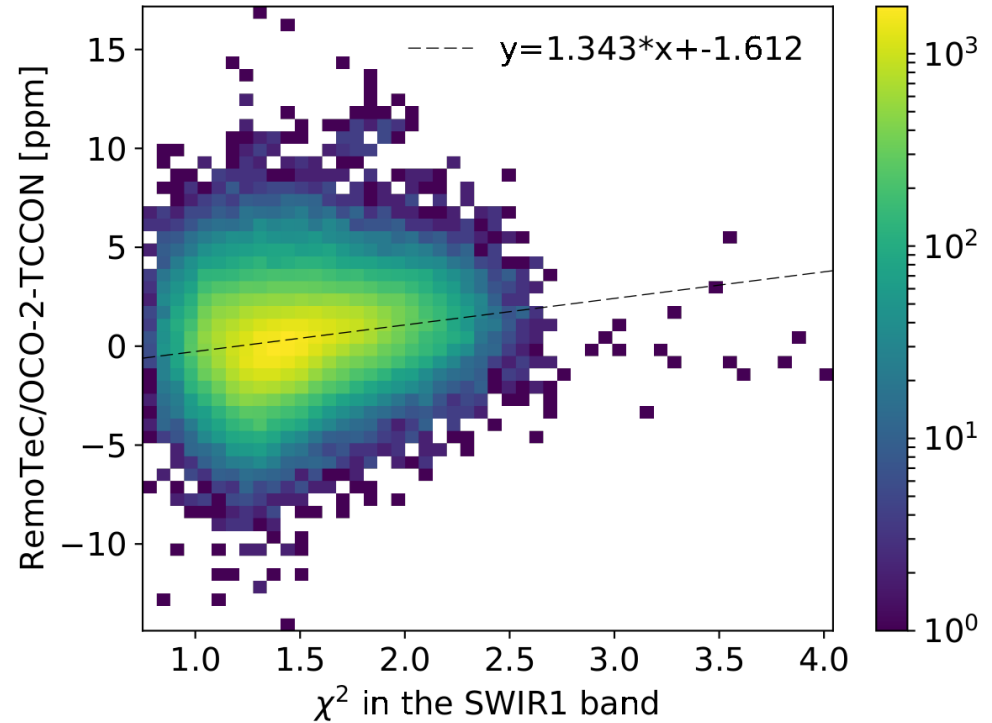In total, **7000 soundings** for each footprint

Bias correction

- **Over Land**

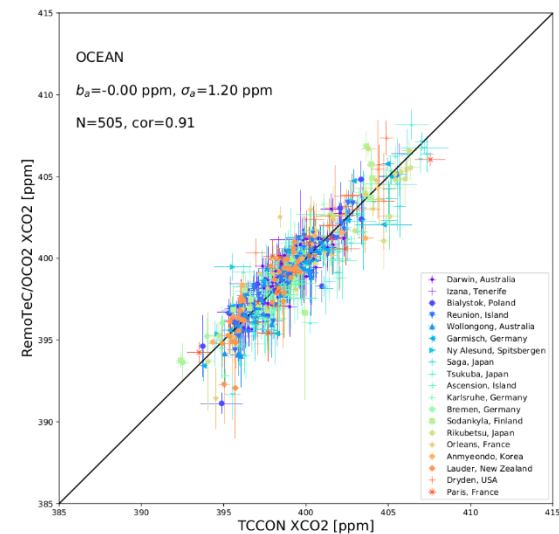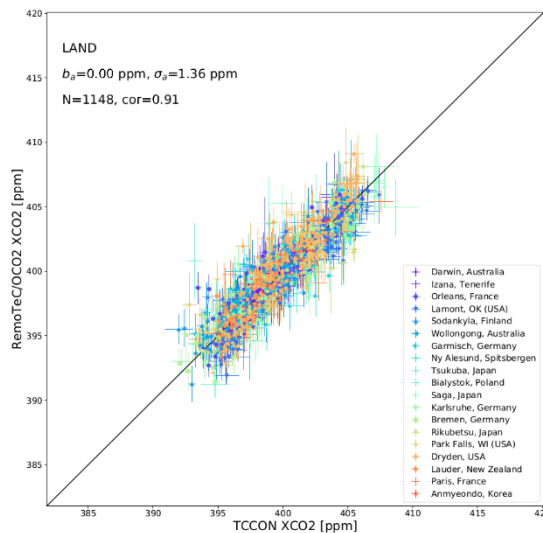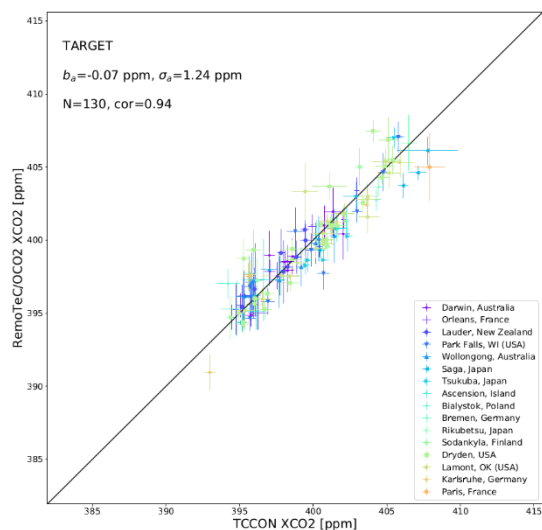$$\mathrm{XCO_2^{corr}} = \mathrm{XCO_2}(d + k \cdot \chi^2),$$

d = 1.001938, k = -0.001261

- **Over Ocean**

Subtract constant bias of 0.65 ppm.

Validation of each overpass

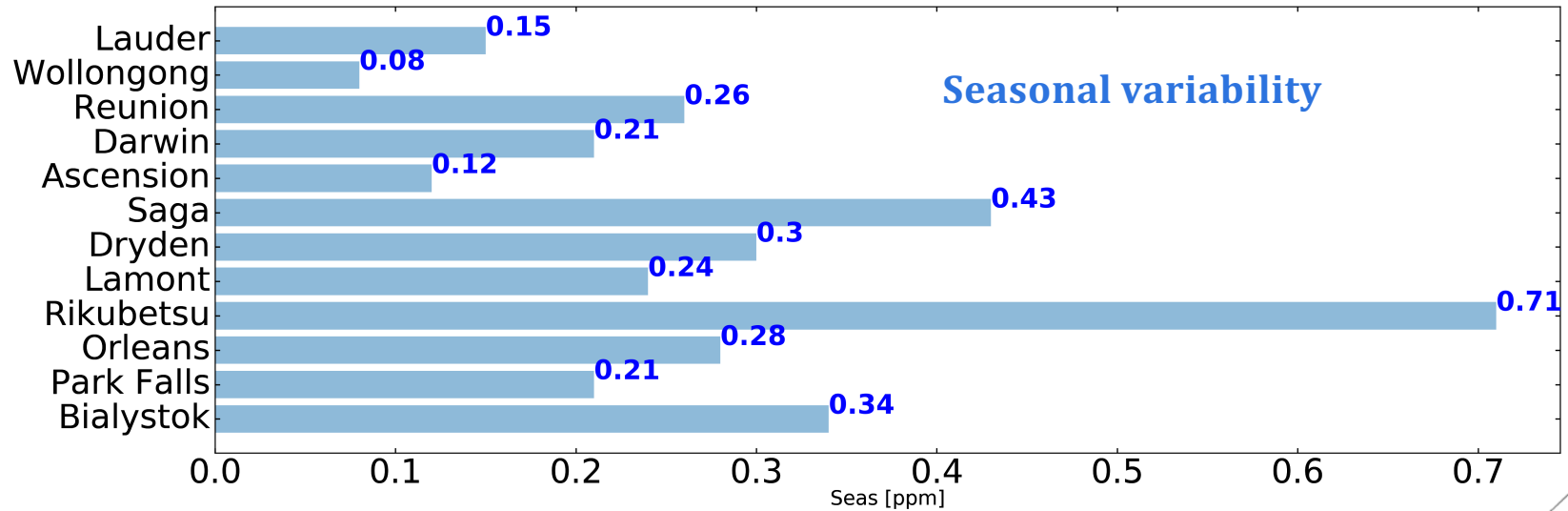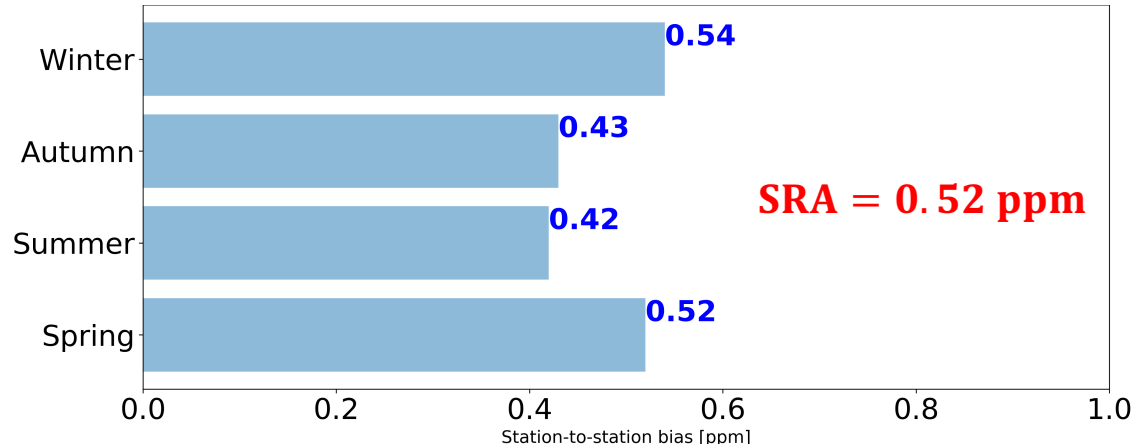|	Target	Land	Ocean
Throughput	15.8%	14.0%	16.0%
N overpass	130	1148	505
Bias [ppm]	-0.07 (0.51)	0.00 (0.44)	0.00 (0.62)
Std [ppm]	1.24 (1.30)	1.36 (1.41)	1.20
Correlation	0.94	0.91	0.91

Station to station variability
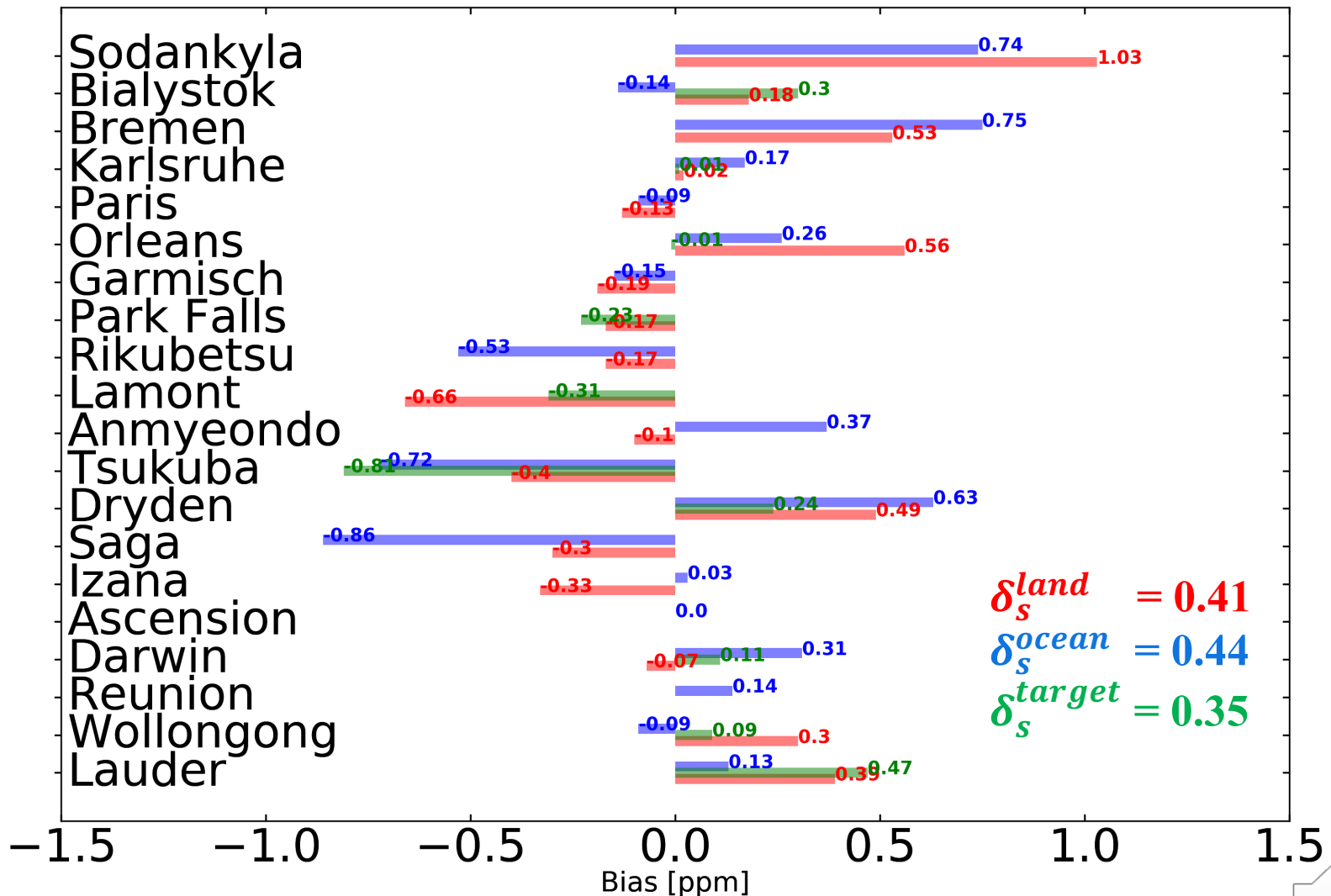
Time variation
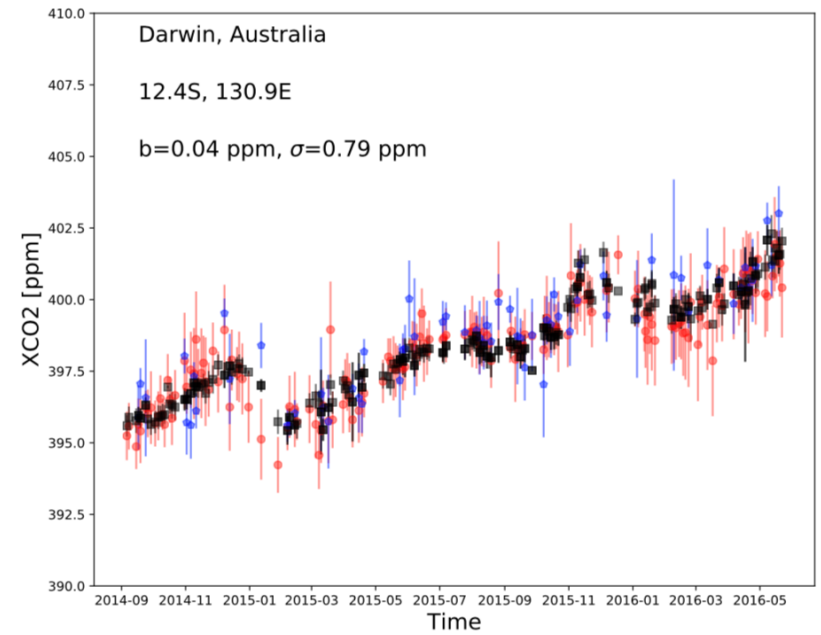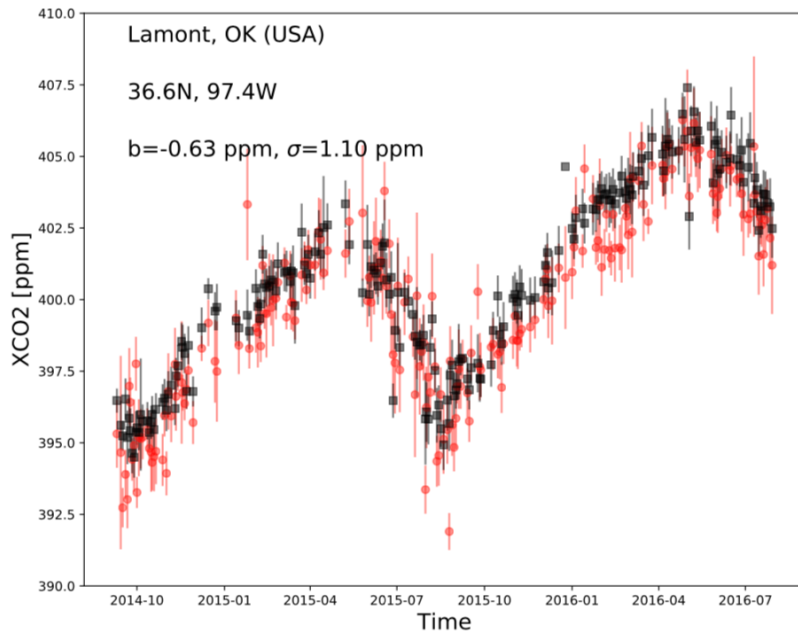
Seasonal relative accuracy (SRA)

Comparison with others

- Published results

Product	Std	Station to station bias	SRA
ACOS/OCO-2	1.3 (average)	0.45 (12 stations)	-
RemoTeC/OCO-2	1.3 (average)	0.41 (17 stations)	0.52
RemoTeC/GOSAT	1.9 (individual)	0.43 (12 stations)	0.51

- **Same dataset** : 34560 single soundings (**30%**), **646** overpass collocated with 18 TCCON stations.

After bias correction	Bias	Std	Station to station bias
ACOS/OCO-2	0.13	1.31	0.55
RemoTeC/OCO-2	-0.02	1.36	0.44

Before bias correction	Bias	Std	Station to station bias
ACOS/OCO-2	-1.04	1.53	0.63
RemoTeC/OCO-2	0.67	1.43	0.47

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Multiple angle retrievals

ECHAM5-HAM

std = 1.89 ppm   **std = 1.32 ppm**
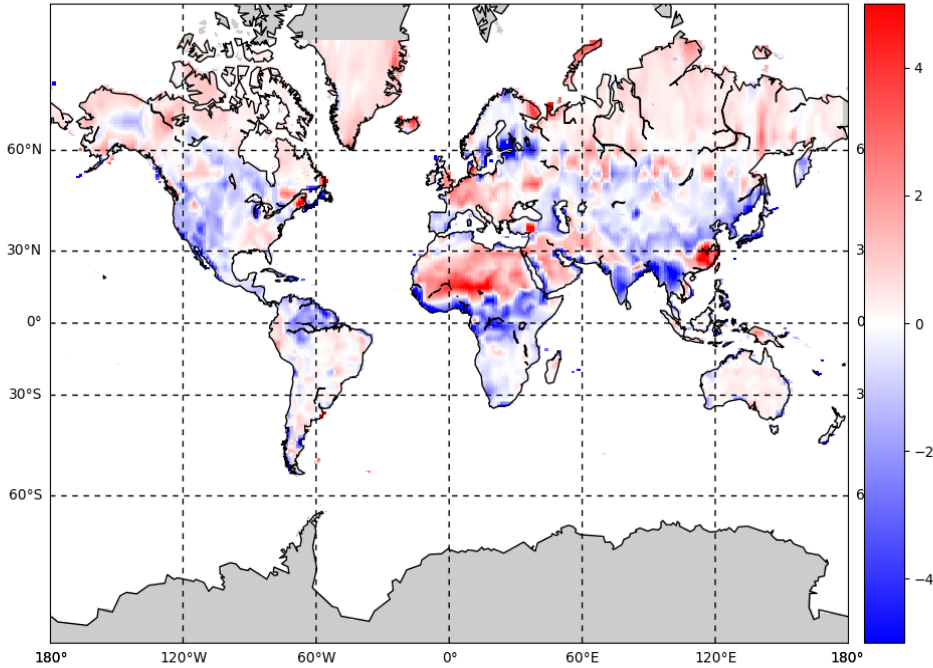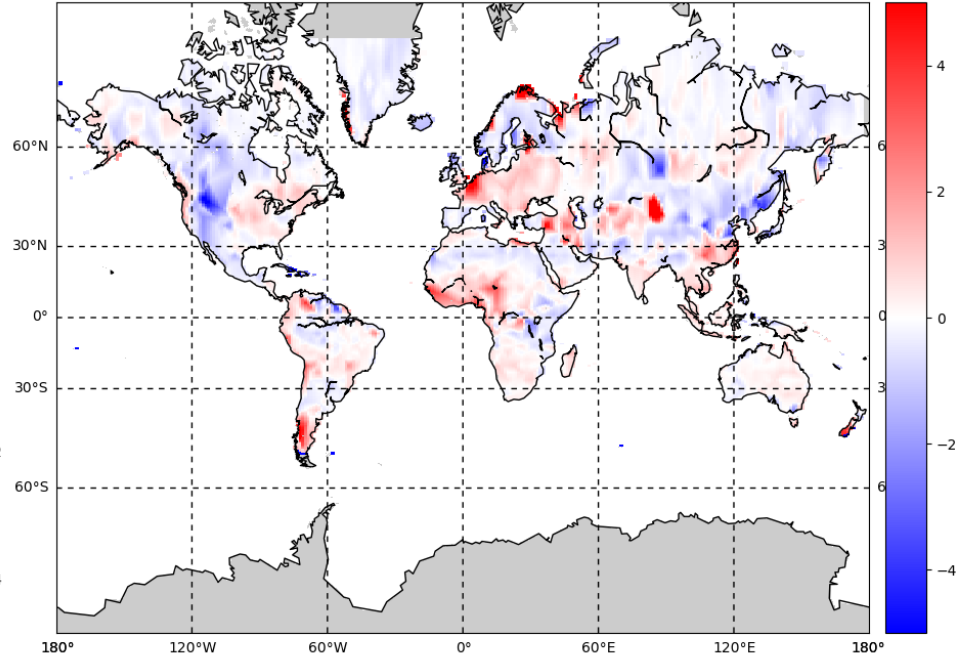
**Nadir Only**   **Multiple viewing**

Conclusion

- RemoTeC has been successfully applied to OCO-2 data;

- Comparison of RemoTeC/OCO-2 retrievals and TCCON data have a standard deviation around **1.30** ppm, a station-to-station variation around **0.40** ppm and a overall seasonal relative accuracy **0.52** ppm;

- Retrievals have relatively larger difference with TCCON in **high latitude areas** and **Japan** area;

- Fitting **an additive intensity offset** for all three bands is very important;

- In synthetic study, by taking advantage of **multiple angle** information, the XCO2 retrieval uncertainties can be reduced by **~0.5** ppm.

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Overall validation
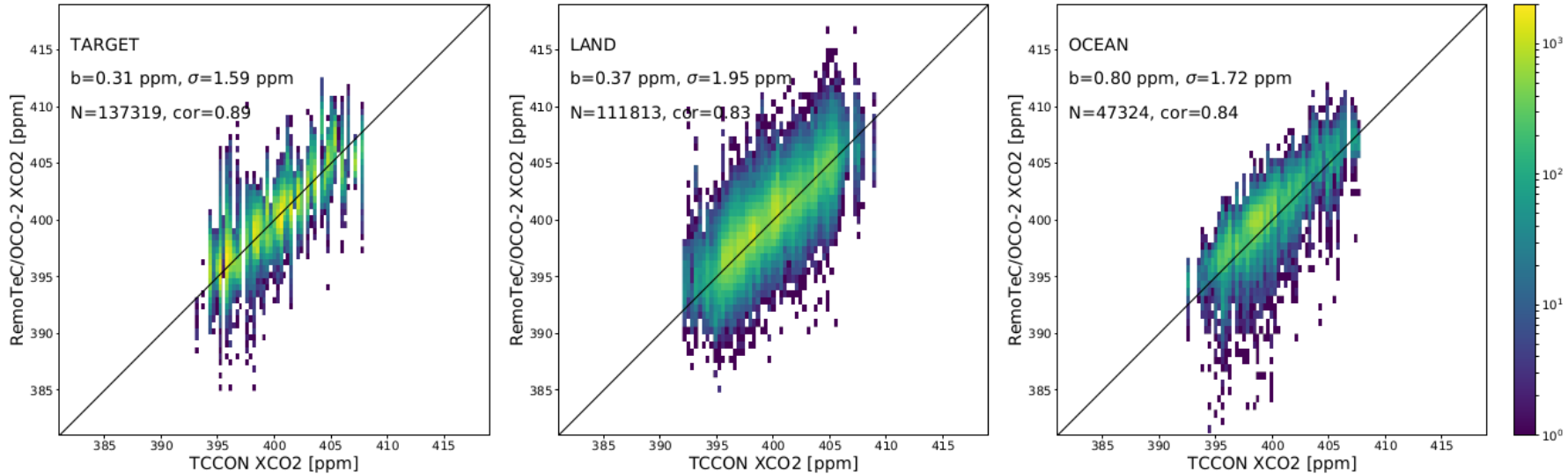
	Target	Land	Ocean
Good quality	66%	50%	47%
Throughput	**15.8%**	**14.0%**	**16.0%**
N soundings	137 K	111 K	47 K
Bias [ppm]	0.31	0.37	0.80
Std [ppm]	**1.59**	**1.95**	**1.72**
Correlation	0.89	0.83	0.84