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Joint Validation of Space-Based XCO_2 and Aerosol Observations at Urban Sites

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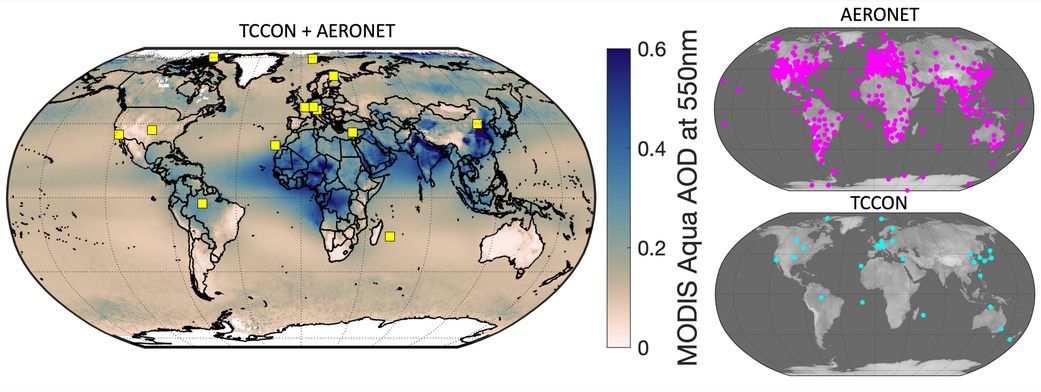
Current Capabilities for Joint XCO_2 - Aerosol Validation

- With the upcoming CO2M mission there is a need to assess current capabilities and future needs for satellite XCO_2 validation in urban environments.
- In this work joint validation of OCO-2 XCO_2 and aerosols are carried out at locations that have both TCCON and AERONET site close to each other
- **Motivation** for this work is to gain understanding of different validation approaches in urban, potentially high aerosol load environments, and to establish the current state of the art and gaps in both XCO_2 retrievals and validation.



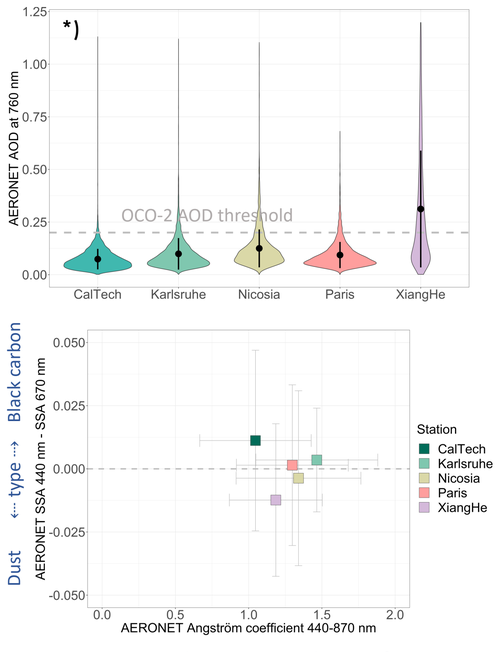
- There are currently 13 locations where TCCON and AERONET stations are located close (<10 km) to each other and have more than one month of overlapping data available (between Sept. 2014-Dec. 2019).

TCCON-AERONET Locations

TCCON	AERONET	Dist. [km]	Environment
Caltech	CalTech	0.5	Urban
Eureka	PEARL	0.4	Arctic
Garmisch	Zugspitse KIT	8.6	Mountain
Izana	Izana	< 0.2	Mountain
Karlsruhe	Karlsruhe	1.2	Urban
Lamont	Cart Site, ARM_SGP	0.7	Rural
Manaus	ARM_Manacapuru	0.4	Rural
Nicosia	Nicosia	< 0.2	Urban
Ny Alesund	Ny_Alesund_AWI	0.4	Arctic
Paris	Paris	0.5	Urban
Reunion	REUNION_ST_DENIS	0.5	Rural
Sodankylä	Sodankylä	0.4	Rural
XiangHe	XiangHe	5.2	Urban

- Five locations can be considered as "urban".
- XiangHe differs from the other urban stations especially by aerosol loading.
- At "other" station types the mean AOD is very low (<0.1).

Aerosol Characteristics at Urban Stations

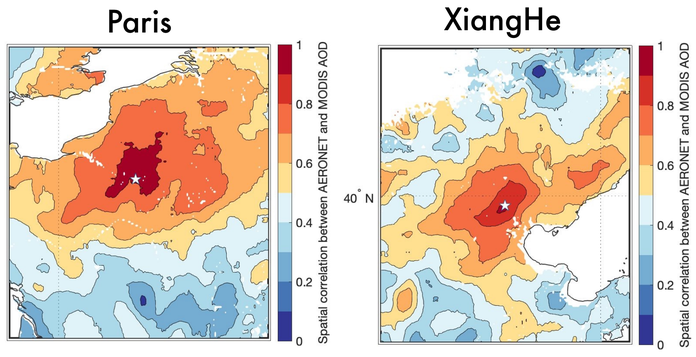


*) AERONET AOD at 760 nm is derived using Angström coefficient and AOD at 870 nm

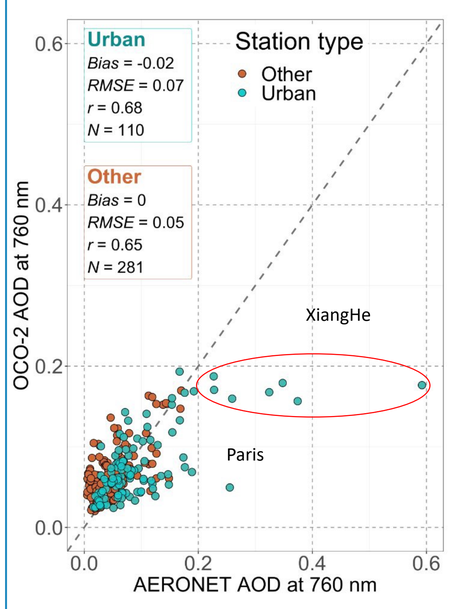
Validation of XCO_2 and Aerosols

- Aerosols have typically much higher variability in space and time than XCO_2 which needs to be considered when carrying out validation.
- For this work spatial representativeness of urban stations for aerosols was analysed by establishing correlations between MODIS Aqua AOD (coll 6.1, 3 km) and AERONET over one year (2019).
- At urban sites the spatial correlation is used as reference to select observations for validation.

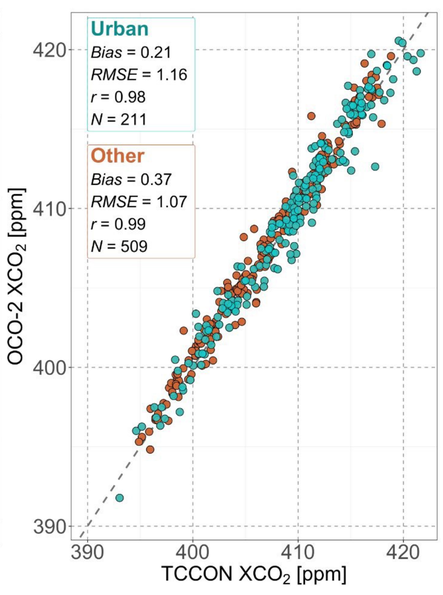
MODIS –AERONET AOD Correlation



AERONET vs. OCO-2 AOD



TCCON vs. OCO-2 XCO_2

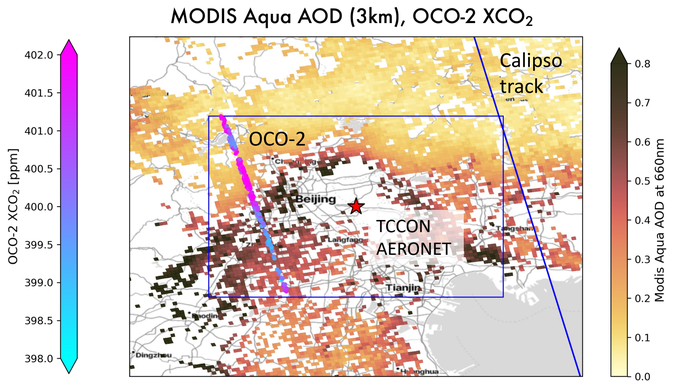


- OCO-2 observations (L2, v.10) were colocated with TCCON and AERONET.
- For good quality XCO_2 retrievals the current threshold for OCO-2 AOD (at 760 nm) is 0.2.
- Results show that for low AODs OCO-2 agreement with AERONET is good.
- Occassional OCO-2 AOD underestimations occur, mainly in XiangHe where AOD can be very high.
- On average the XCO_2 bias at all stations (urban, other) remain below ± 1 ppm.

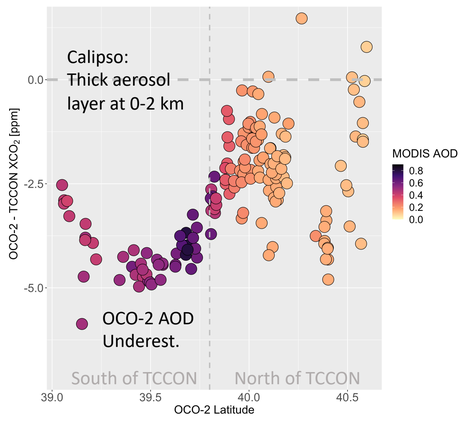
Case Studies

- For more detailed case studies OCO-2 observations were colocated with MODIS Aqua AODs.
  - Supporting observations from CALIPSO (space-borne lidar) for aerosol vertical distribution were used when available.
- With this combination of observations detailed analysis on single overpasses can be carried out and potential risks for aerosol-induced biases can be assessed.
- The analysis was done for OCO-2 overpasses at urban stations with varying aerosol conditions for years 2014-2020.

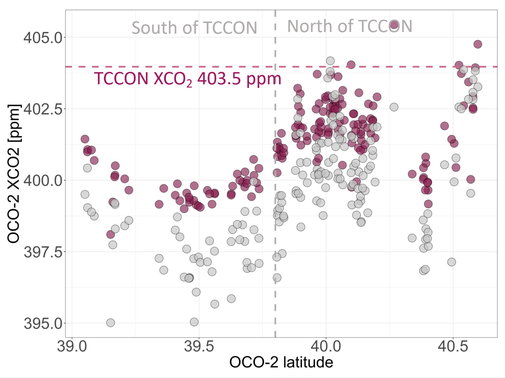
XiangHe 25.8.2018



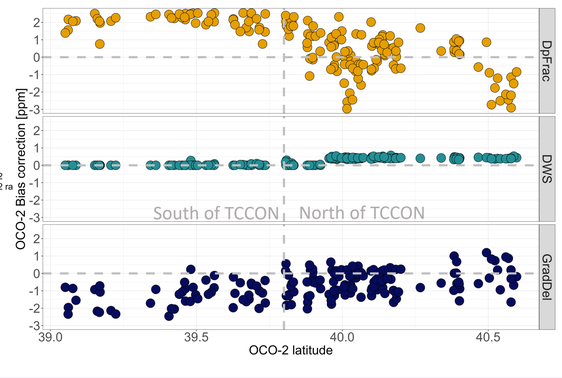
OCO-2 single sounding XCO_2 difference to TCCON



OCO-2 "raw" vs. "corrected" XCO_2



OCO-2 Bias correction terms



Summary

- Currently there are 13 locations, where joint validation of XCO_2 and aerosols against ground-based measurements is possible.
  - Five stations can be considered as urban.
  - Majority of these stations are located at low aerosol concentration environments, where risks for aerosol induced biases are low.
  - These 13 locations do not represent well global aerosol regimes; missing stations e.g. in India and Africa.
- Joint validation of XCO_2 and aerosols show that OCO-2 estimates AOD well for the most part, however, underestimations can occur at high aerosol load cases.
- **On average** the OCO-2 XCO_2 bias remains low (less than ± 1 ppm), regardless of station type.
- Detailed case studies can give more insight on the XCO_2 retrieval at highly variable aerosol conditions.
- Case studies didn't show any clear indication that the XCO_2 bias would systematically depend on prevailing AOD conditions, even though OCO-2 would miss some of the high AOD cases.

Developing methods and infrastructure for a coordinated validation of aerosols and CO_2 is vital for the success of planned CO2M mission due to its requirement to make observations for emission estimation in larger aerosol loadings.

Global perspective on Aerosol Effect and XCO_2 Retrievals, Talk by Timo Virtanen, Wed 29.5. (Day 1), 4:30 PM

References:

[1]O'Dell, C. et al.: Improved Retrievals of Carbon Dioxide from the Orbiting Carbon Observatory-2 with the version 8 ACOS algorithm, *Atmos. Meas. Tech.*, 11, 6539–6576, 2018.

[2] Orbiting Carbon Observatory -2 & 3, Level 2 Full Physics Retrieval, Algorithm Theoretical Basis, Version 2, JPL, 2019.

This work is funded by Academy of Finland project CitySpot (grant agreement 331829)