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Evaluating consistency between total column CO_2 retrievals from OCO-2 and the *in-situ* network over North America: Implications for carbon flux

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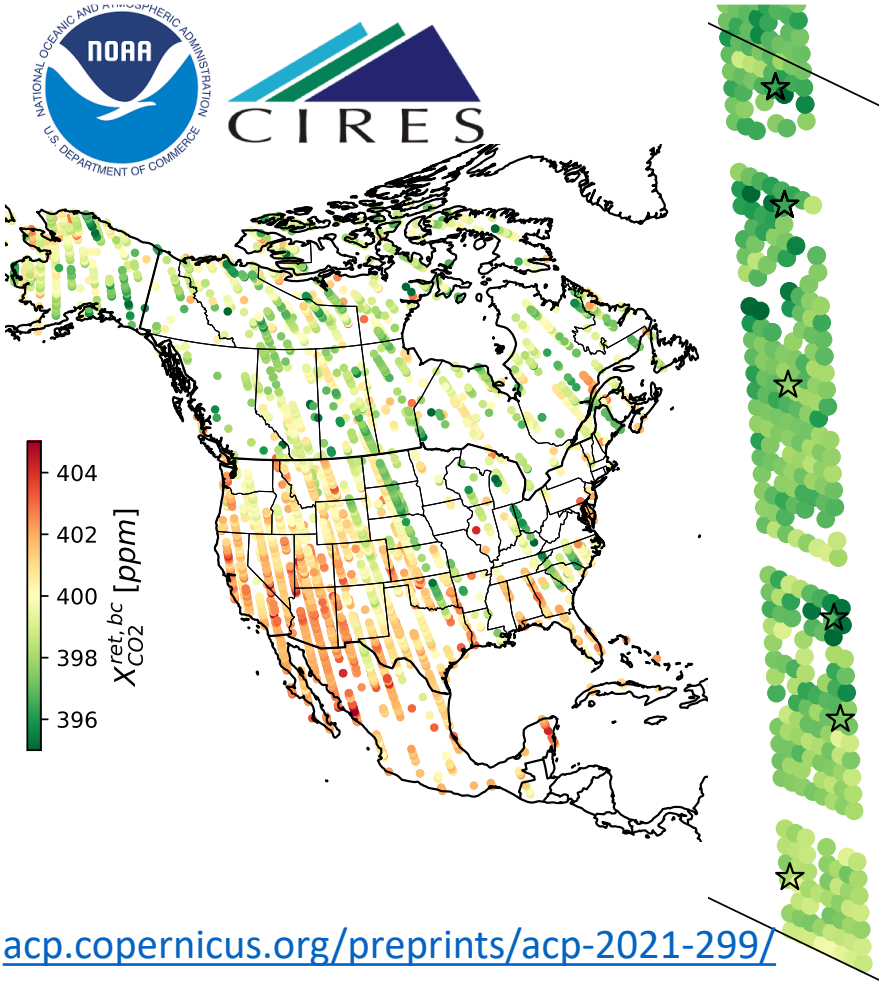
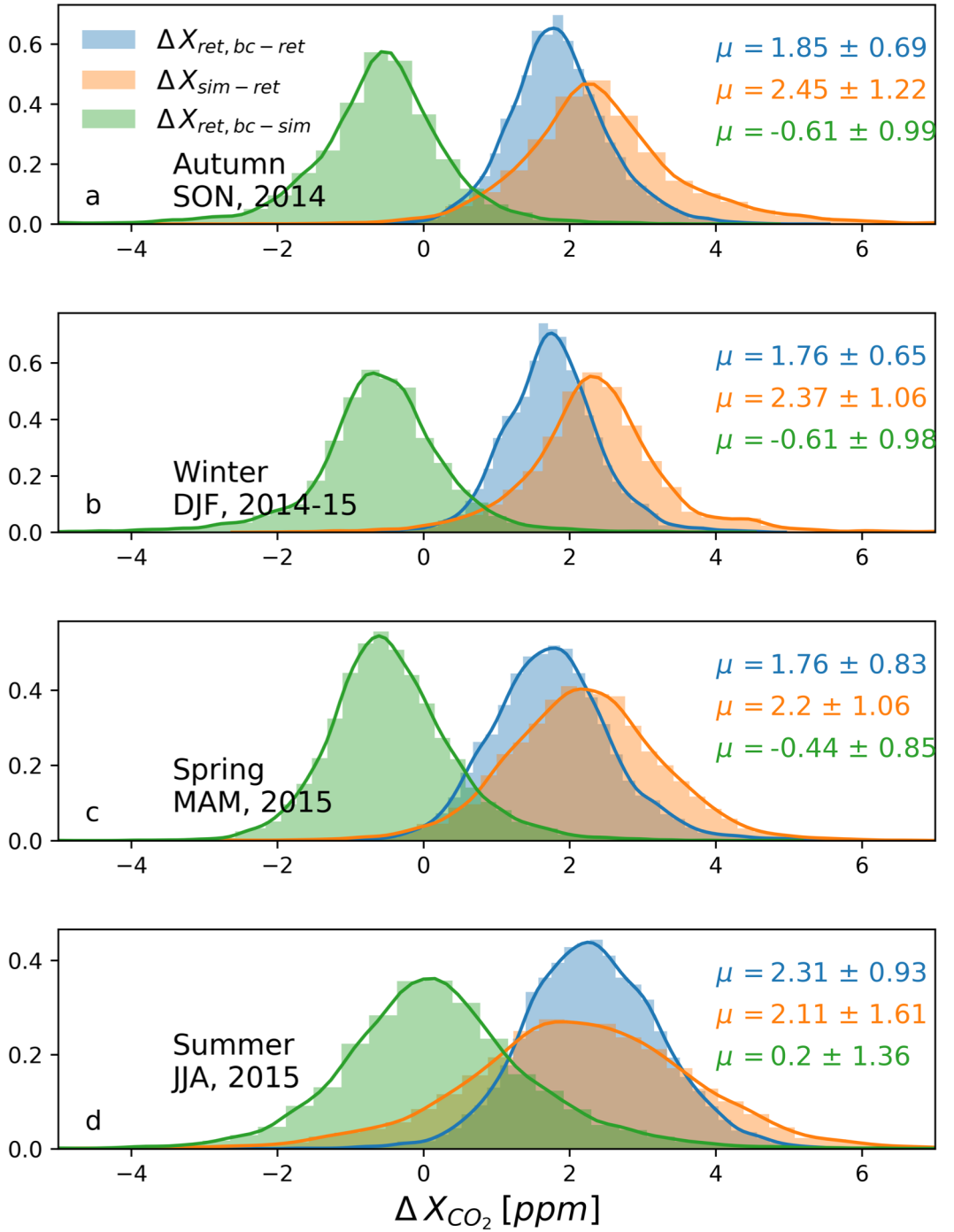


- High res. transport model used to evaluate OCO-2 b10 (*LNLG*) data over North America
- XCO_2 simulated using 24 combinations of fluxes and boundary conditions (both constrained by *in-situ* obs)
- Potential OCO-2 bias small, seasonally and spatially variable, AND similar to total column flux impacts



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NASA CMS: Guan2016

Evaluating consistency between total column CO_2 retrievals from OCO-2 (v10) and the *in-situ* network over North America: Implications for carbon flux estimation

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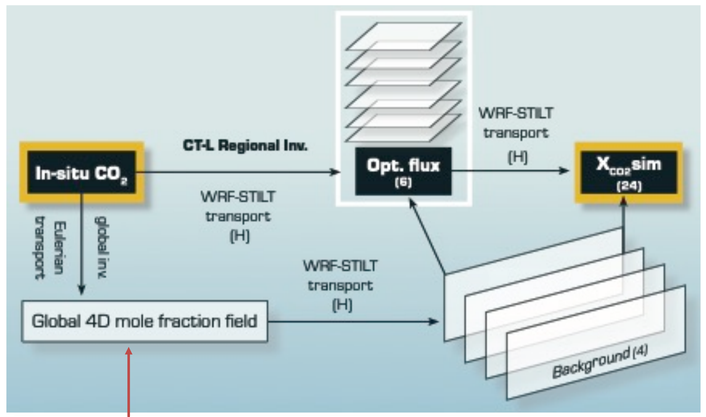
Introduction

- Carbon climate feedbacks are a key source of uncertainty in ESMs.
- In part due to the inability of measuring large scale biosphere-atmospheric carbon fluxes, e.g. GPP
- Inverse models infer net surface flux from measurements of CO_2 mole fraction, but are limited by spatial coverage of measurement networks
- Satellite retrievals of total column CO_2 mole fraction (XCO_2) can fill this gap, but these need to be highly precise since even large surface flux signals are mediated in the total column by atmospheric transport

To evaluate satellite retrievals and assess potential bias, we compare OCO-2 with CO_2 columns over North America (NA) constrained by in-situ data calibrated to the WMO X2007 scale

Methods

- We use STILT transport model and WRF meteorology to generate sensitivity matrices corresponding to XCO_2 retrieval locations (receptor) 2s along-track over temperate NA and 4s along track over boreal NA.
- WRF-STILT run at 10 km x 10 km over temperate and at 30 km x 30 km over boreal NA
- Background from 4-D mole fraction fields
- Biospheric flux (NEE) estimates from CarbonTracker Lagrange[1] optimally consistent with in-situ CO_2 surface observations calibrated to WMO X2007 scale
- 4 realizations of background x 6 NEE ensembles **= 24 flux background combinations**



(CT 2016, CT 2019B, CAMS v18r3, Jena-Carboscope v4.3)

Constructing $X_{CO_2}^{sim}$

$$X_{CO_2}^{sim} = \sum w_i \left[a_i . \chi_{CO_2,i}^{model} + (1 - a_i) . \chi_{CO_2,i}^{prior} \right] \quad \text{(eq.1)}$$

$$\chi_{CO_2,i}^{model} = \chi_{CO_2,i}^{bkg} + \Delta CO_2, i$$

$X_{CO_2}^{sim}$: simulated OCO-2 XCO_2

$\chi_{CO_2}^{prior}$: OCO-2 prior profile

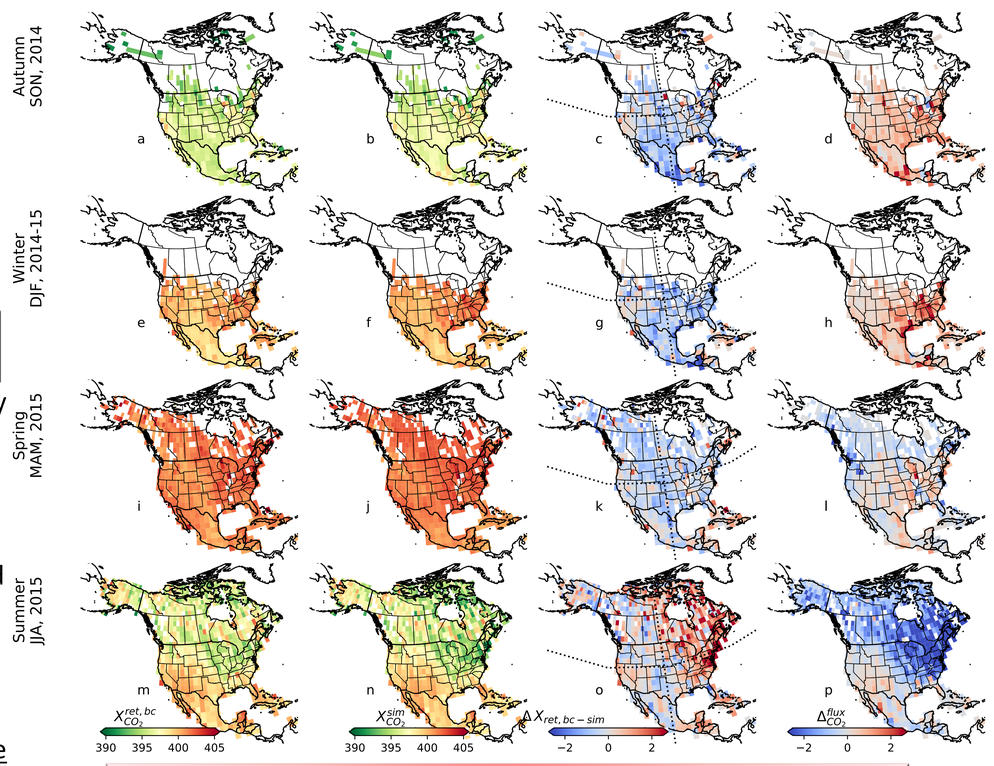
$\chi_{CO_2}^{model}$: modeled column CO_2 profile

a_i : averaging kernel

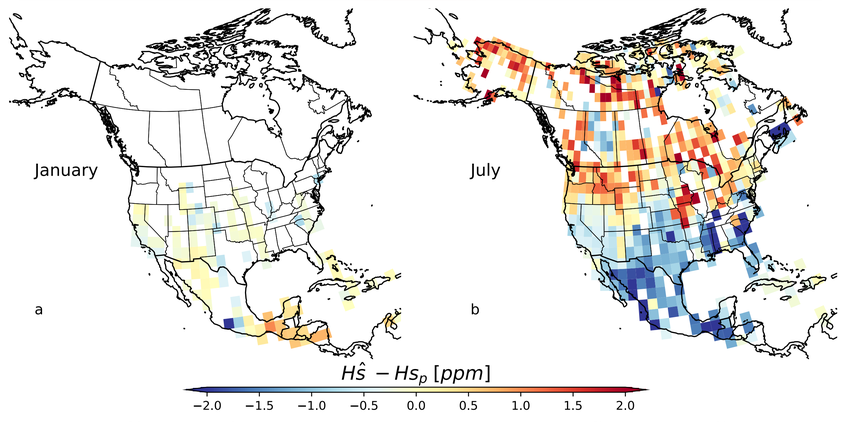
w_i : pressure weighting function

$\Delta CO_2, i$: Impact of recent surface flux

Comparing OCO-2 and $X_{CO_2}^{sim}$

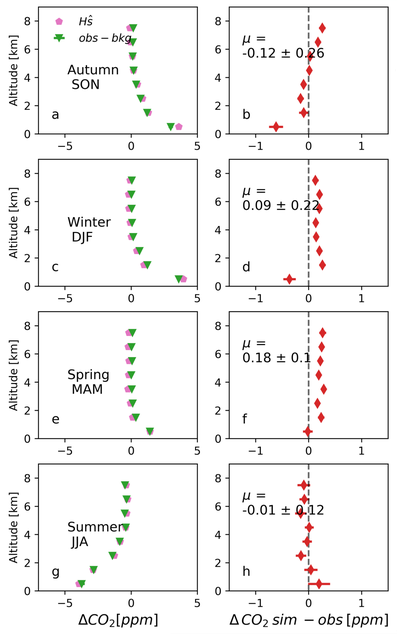


How big is the surface flux signal?

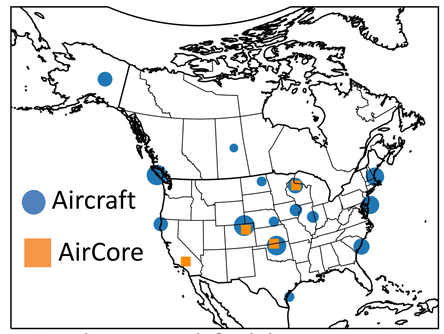


Difference between prior and optimized flux is small, when projected onto the total column [ppm]

Examining bias + uncertainty in $X_{CO_2}^{sim}$



Using *Unassimilated* (independent) profiles from Aircraft (0 - 8 km) & AirCore (> 8 km)



Background fields vs AirCore*

Season	CT 2016	CT 2019B	CAMS	CarboScope
Autumn	0.59 ± 0.02	0.77 ± 0.01	0.27 ± 0.01	0.95 ± 0.02
Winter	0.57 ± 0.01	0.74 ± 0.01	0.34 ± 0.01	1.99 ± 0.02
Spring	−−	1.40 ± 0.03	0.76 ± 0.03	3.31 ± 0.07
Summer	0.4 ± 0.04	0.45 ± 0.02	−0.11 ± 0.02	0.73 ± 0.03

* errors reduce once weighted according to a_i, w_i

$X_{CO_2}^{sim}$ error

Season	$\sigma_{X_{CO2}^{sim}}$	$\Delta X_{ret,bc-sim}$	Bias in $X_{CO_2}^{ret,bc}$	Bias in $X_{CO_2}^{ret,bc}$ *v9-LN*
Autumn	−0.01 ± 0.31	−0.61 ± 0.99	−0.62 ± 0.99	−0.88 ± 1.00
Winter	0.25 ± 0.35	−0.61 ± 0.98	−0.36 ± 0.98	−0.76 ± 1.10
Spring	0.50 ± 0.31	−0.44 ± 0.85	0.06 ± 0.85	0.07 ± 0.99
Summer	0.05 ± 0.40	0.20 ± 1.36	0.25 ± 1.36	0.14 ± 1.38

Conclusions

- We compare one year of OCO-2 XCO_2 (v10 LNLG) over NA against synthetic columns using high-res. regional transport model + fluxes & background optimally consistent with in-situ network tied to WMO X2007 scale
- Unresolved variability in $X_{CO_2}^{sim}$ ~ 0.15 ppm ~ to long term measurement uncertainty of NOAA's in-situ network
- $X_{CO_2}^{sim}$ bias varies seasonally, usually lower than reported uncertainty of $X_{CO_2}^{ret,bc}$
- OCO-2 v10 global bias correction greatly improves the quality of OCO-2
- However, significant differences present seasonally and at sub-continental scales (e.g., in the summer)
- Other than spring (MAM), disagreement between $X_{CO_2}^{sim}$ and $X_{CO_2}^{ret,bc}$ due to potential bias in the latter
- Potential bias is small but similar to the total column flux signal and larger than the *expected flux signal* i.e., flux adjustment in an atmospheric inversion
- Continued retrieval development and bias correction improvements for existing and planned satellite missions are necessary
- Such analyses possible over NA due to dense highly calibrated in-situ network

Link to manuscript/Funding/Reference

Manuscript available at https://acp.copernicus.org/preprints/acp-2021-299/

Funding: NASA CMS grant Guan (CMS 2016)

[1]Hu et al., 2019; Sci adv. [eq.1]ACOS Data users guide.