Lower-tropospheric CO_2 from near infrared GOSAT observations

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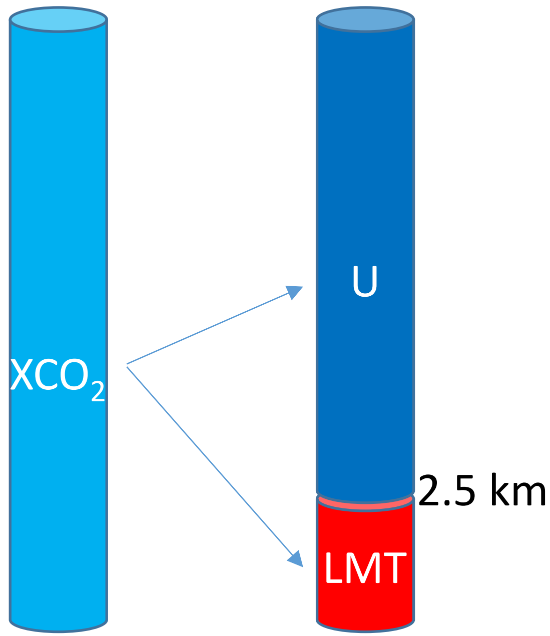
Science goal:

Create lower tropospheric GOSAT and OCO-2 products **to improve carbon cycle flux estimates**



- Concurrent observations in the free troposphere and boundary layer constrain transport error, e.g. partitioning between NH and SH land uptake (Stephens, 2007)
- Near-surface observations allow separation of local vs. transported CO_2 sources
- Sensitivity to the entire boundary layer partially mitigates one source of flask assimilation error, the boundary layer height (Denning et al., 1996; Gurney et al., 2002; Rayner and O'Brien, 2001)

Introduction

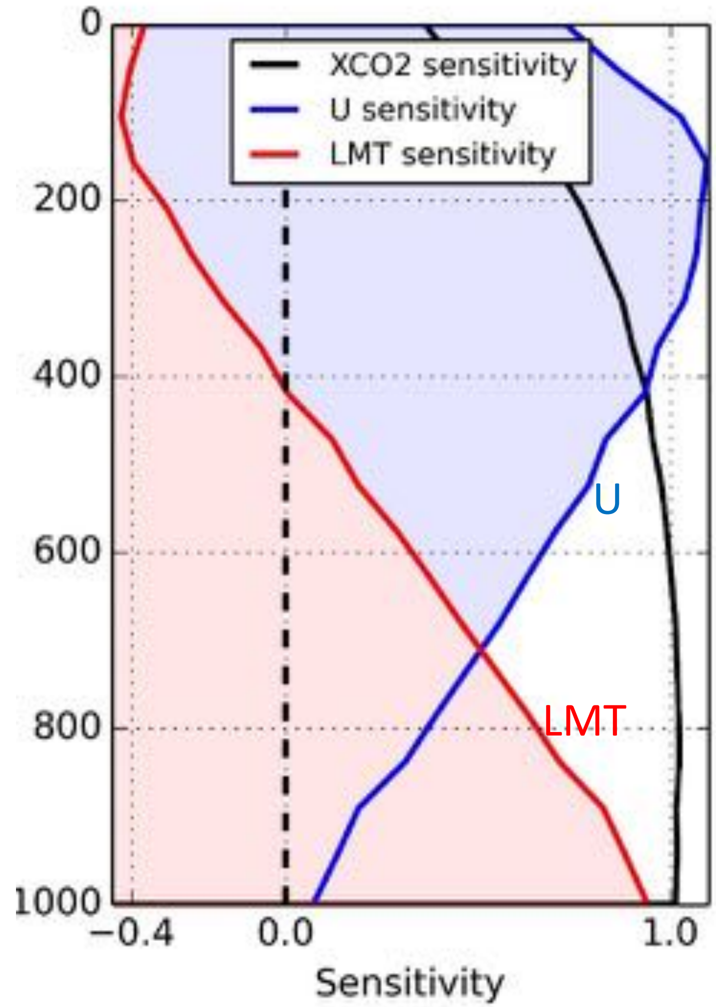
- ACOS-GOSAT retrieves CO_2 profiles and collapses each profile into a column value at the final step
- We partition the intermediate CO_2 profile into two partial columns: lower most troposphere ("LMT"), the bottom 5 levels, and the upper column ("U"), the top 15 levels.
- The LMT partial column is bias corrected using the method of O'Dell (2011). LMT is subtracted from the corrected XCO_2 to generate U, so that U and LMT are consistent XCO_2.

This talk

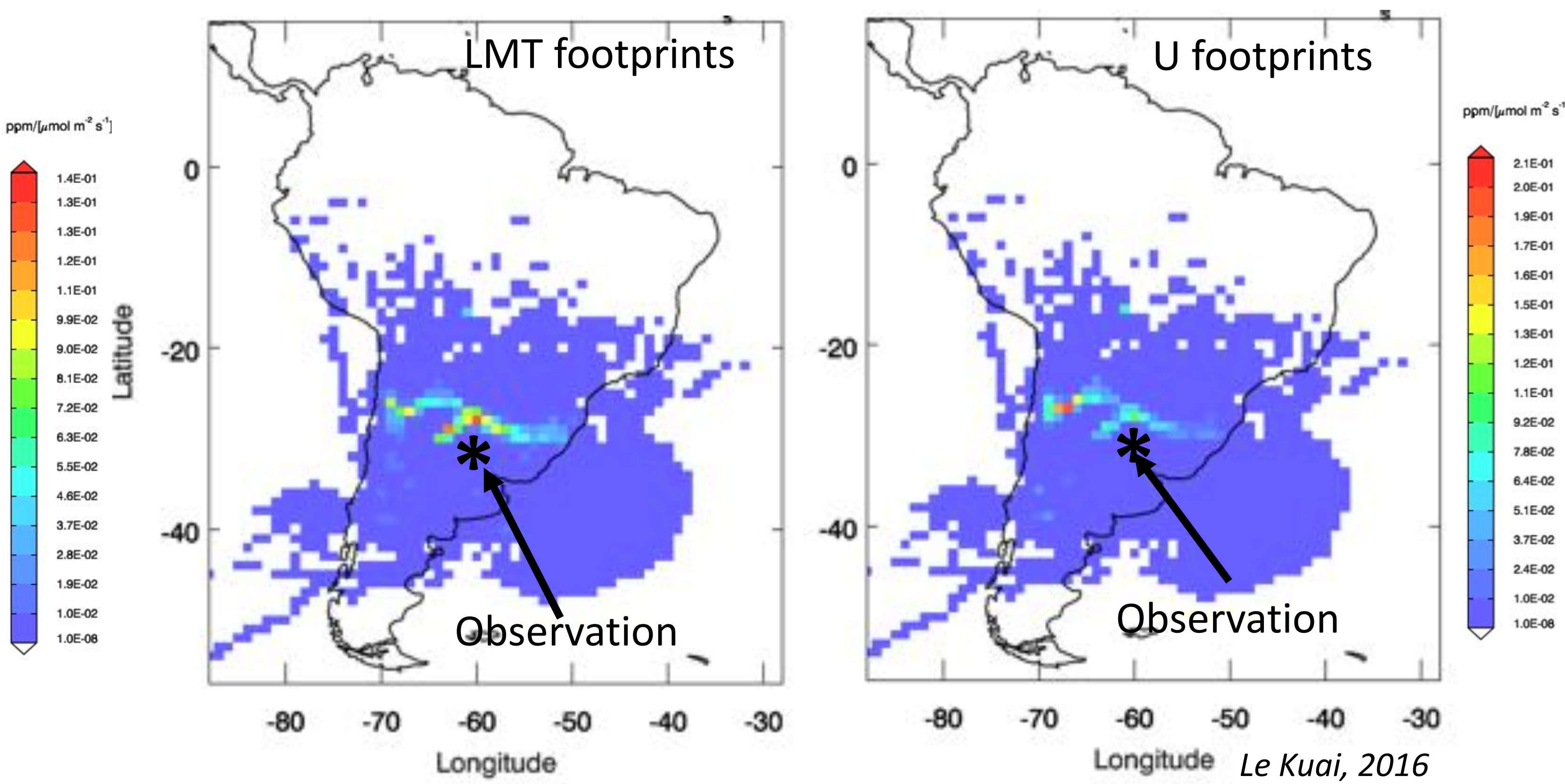
- Expected and actual comparisons to aircraft profiles
- LMT and U compared to aircraft profiles and remote ocean sites
- SH biomass burning– source versus outflow (compares to MOPITT multispectral CO)
- Explore previously observed longitudinal gradient of the seasonal cycle in 45-50N with LMT and U

Sensitivity

- GOSAT degrees of freedom (~1.6) are partitioned about equally at 0.8 for LMT and 0.8 for U.
- LMT sensitivity (red) peaks at the surface and drops off to 0 by 400 hPa
- U sensitivity (blue) is ~0 at the surface and increases to max at ~400 hPa
- The behavior in the stratosphere is partly a consequence of the current constraint.



LMT is more locally influenced than XCO_2



Le Kuai, 2016
Footprints from Janusz Eluskiewicz

Back-trajectories from the 20 OCO-2 pressure levels summed over
Left: LMT averaging kernel, Right: U averaging kernel

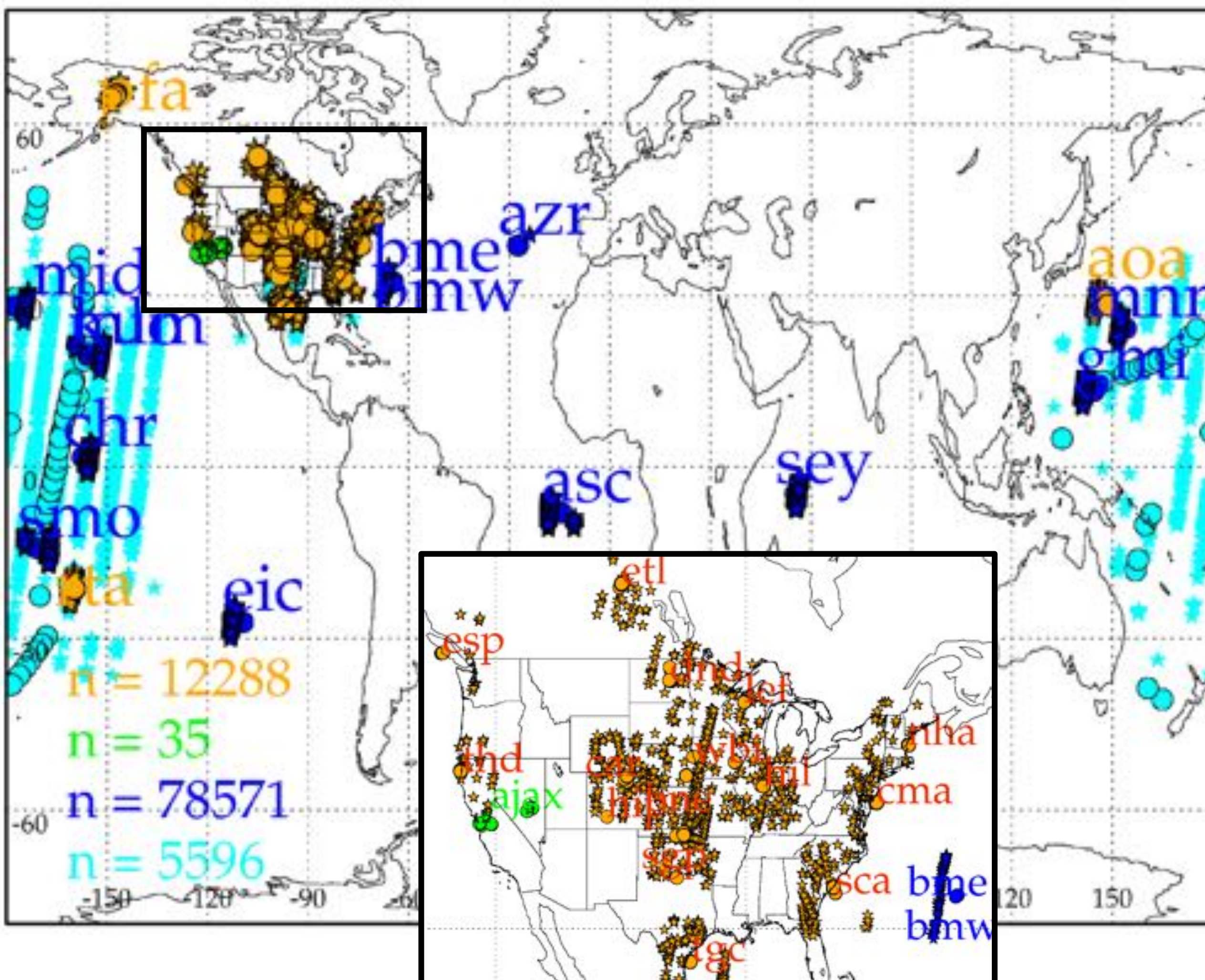
Validation comparisons

ESRL aircraft observations

HIPPO campaign

remote ocean surface sites

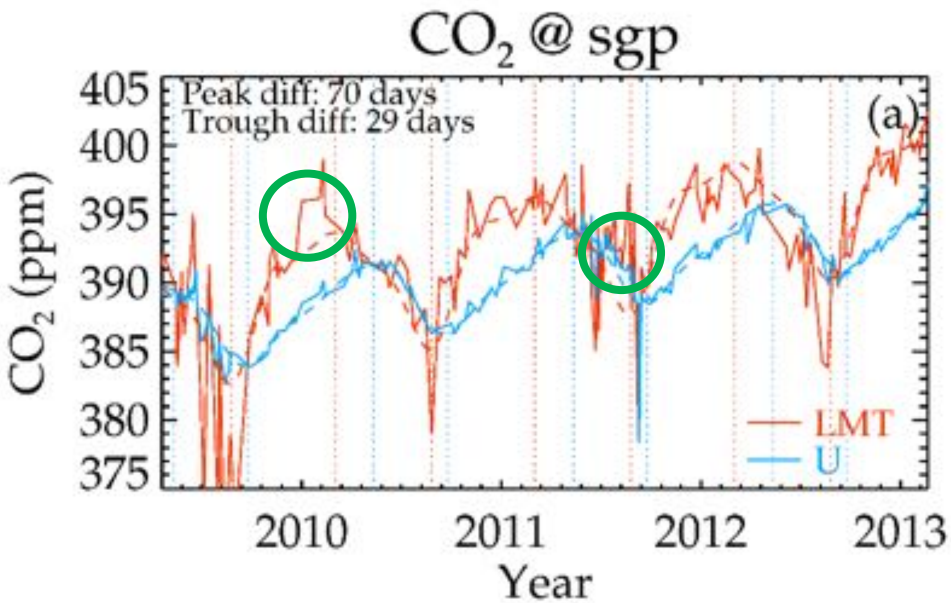
coincidence: 3 degrees x 3 degrees x 7 days coincidence (to check seasonal cycle)



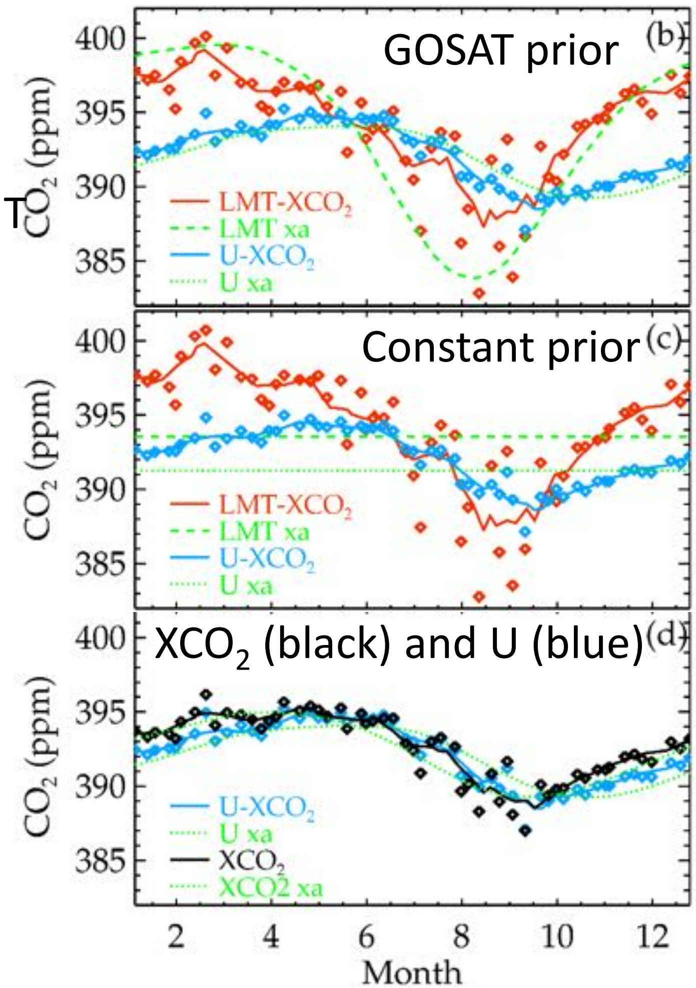
Should this work?

Simulated GOSAT retrievals using SGP aircraft profiles

- Using $\mathbf{x_{ret} = x_a + A(x_{aircraft} - x_a)}$
- Simulated GOSAT LMT (red) and U (blue) retrievals
- Prior choice has limited impact (b,c)
- By looking at the air mass factors and variabilities of U and LMT:
  - 70% of XCO_2 variability is from U, 30% from LMT

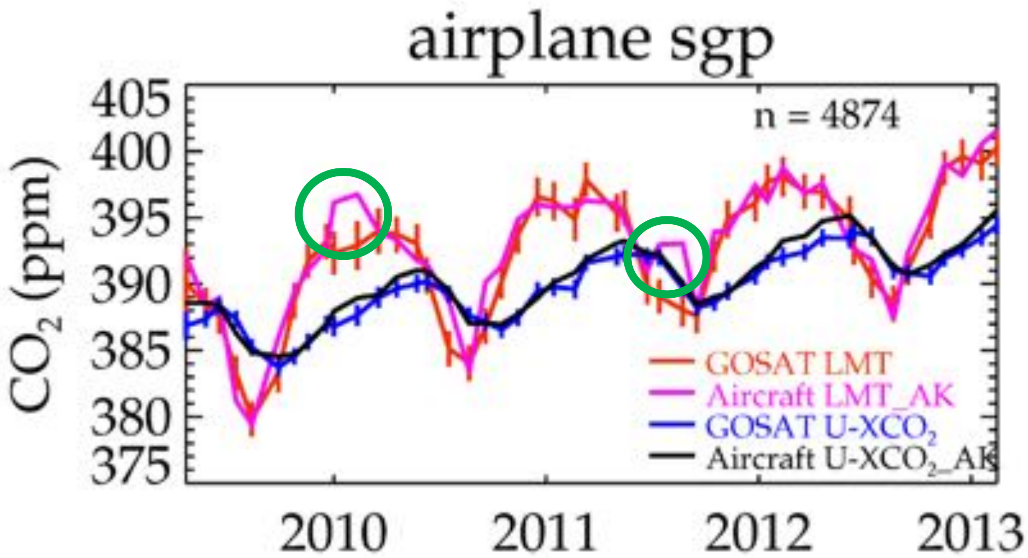


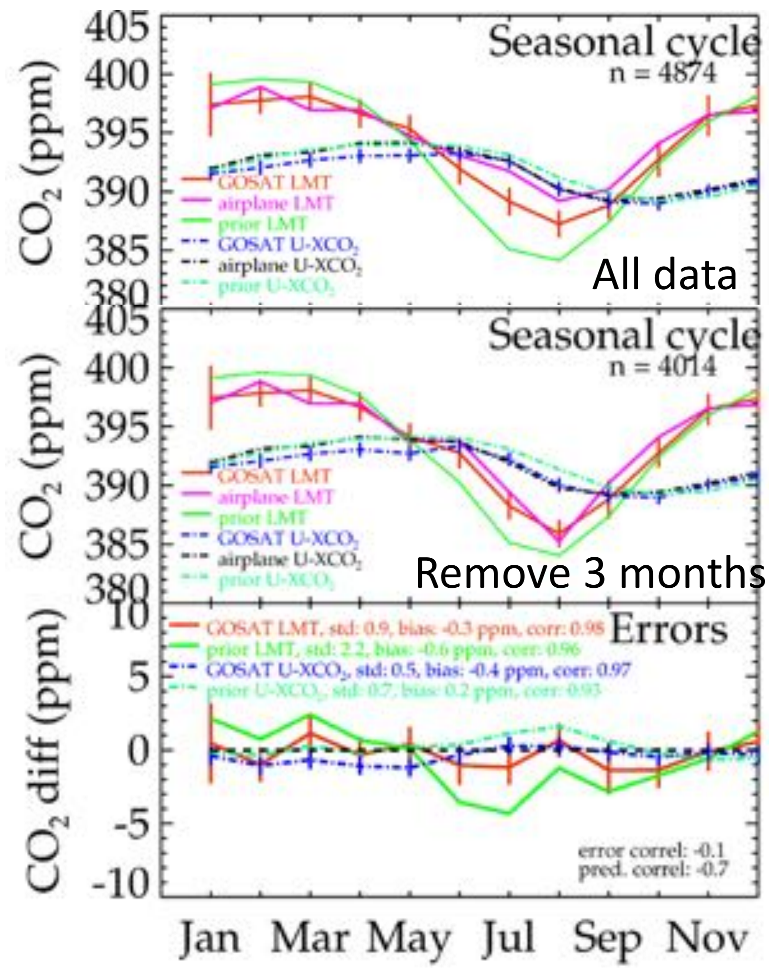
Average over 3 years



Does it work?

Actual GOSAT retrievals vs. SGP aircraft

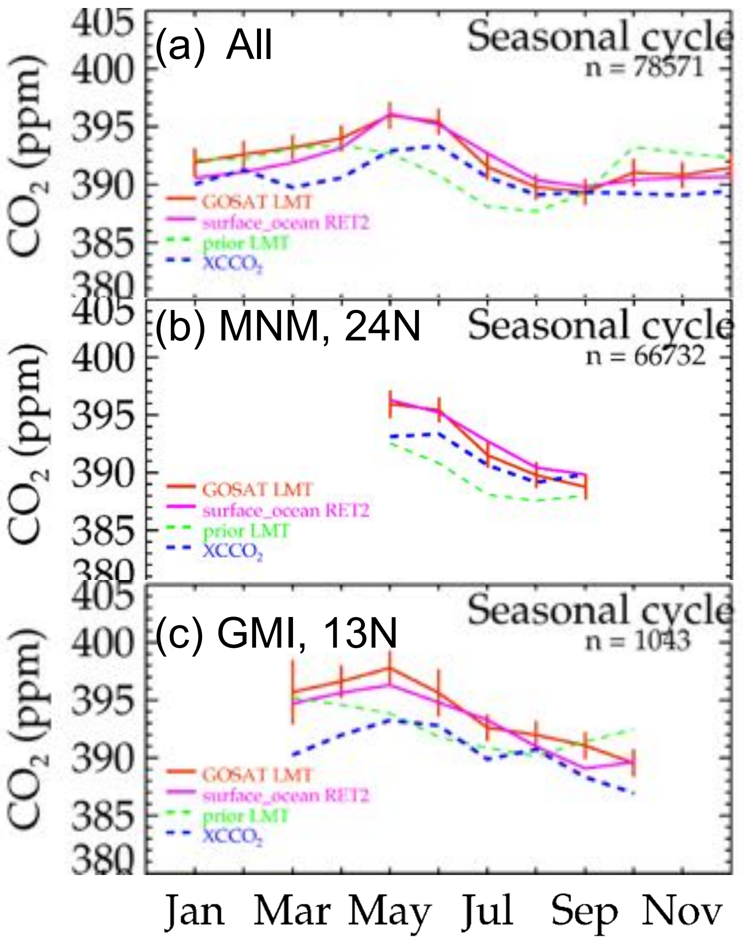




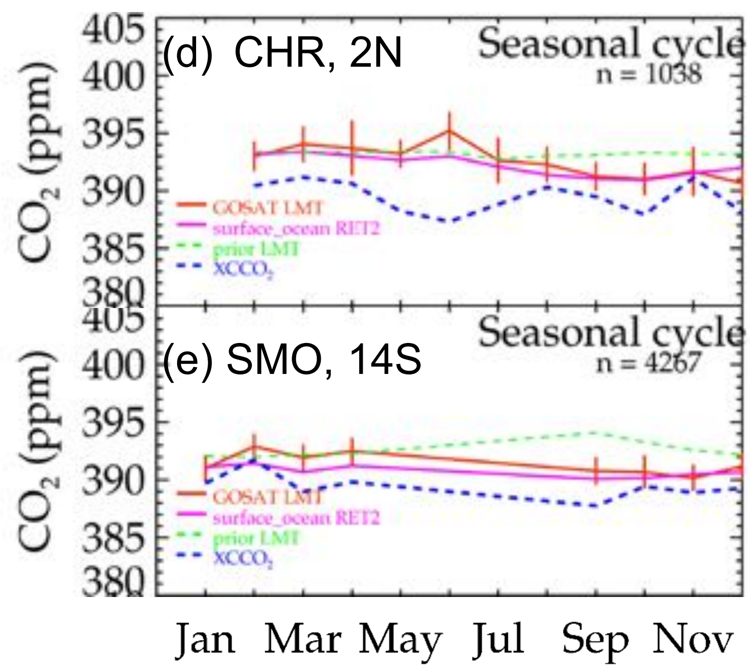
GOSAT improves over the prior

Taking out 3 months where aircraft are anomalous results in very good agreement

Comparisons to surface ocean sites



GOSAT (red) compares to surface data (pink)
Prior (green dashed) does not agree well
XCO2 (blue dashed) does not agree well



LMT, U and XCO_2 overall performance

LMT:	Ocean	Land
Predicted error:	4.3 ppm	4.6 ppm
Single observation error:	1.6 ppm	3.4 ppm
Error for 15 averages:	0.7 ppm	1.3 ppm
Location-dependent biases:	1.1 ppm	1.0 ppm

U:		
Predicted error:	1.7 ppm	1.8 ppm
Single observation error:	0.8 ppm	1.3 ppm
Error for 15 averages:	0.5 ppm	0.5 ppm
Location-dependent biases:	0.1 ppm	0.9 ppm

XCO2:		
Predicted error:	0.7 ppm	0.9 ppm
Single observation error:	0.9 ppm	1.7 ppm
Error for 15 averages:	0.5 ppm	0.6 ppm
Location-dependent biases:	0.4 ppm	0.9 ppm

Green = improves over prior
Red = worse than prior

Results used to calc. error bars used in this presentation

- **LMT, U actual errors less than predicted, whereas XCO2 are larger**
- **Actual LMT-U error correlations are +0.6 rather than the predicted -0.8**
- **This update to the error covariance makes errors consistent but does not work well in assimilation (work by F. Deng)**

S. Kulawik

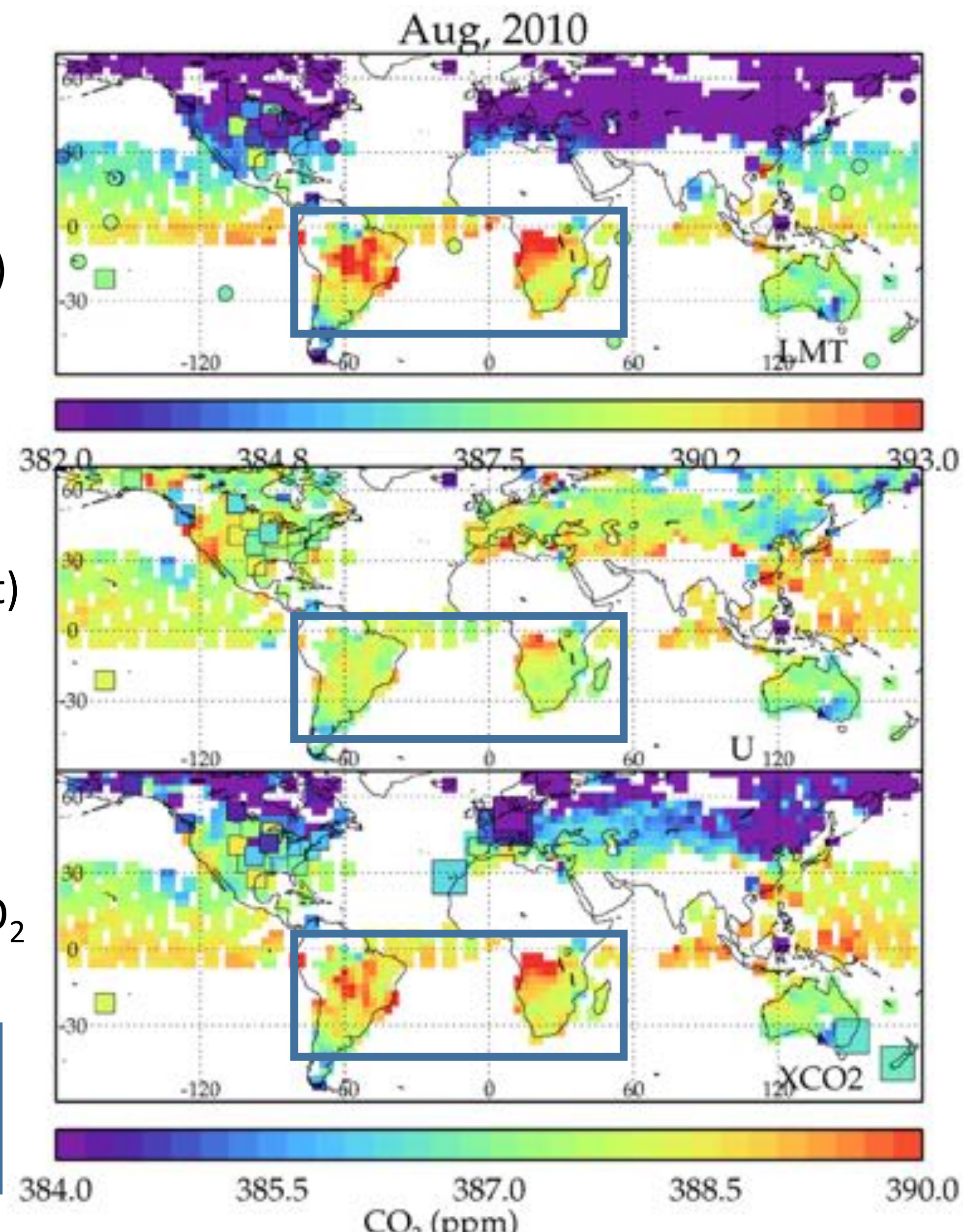
August, 2010. SH biomass burning

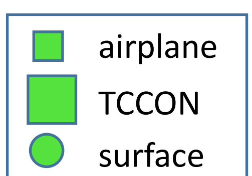
In August, GOSAT LMT shows biomass burning in Amazon but NOTHING in U. In Africa a bit in U.

GOSAT LMT
(lower trop)

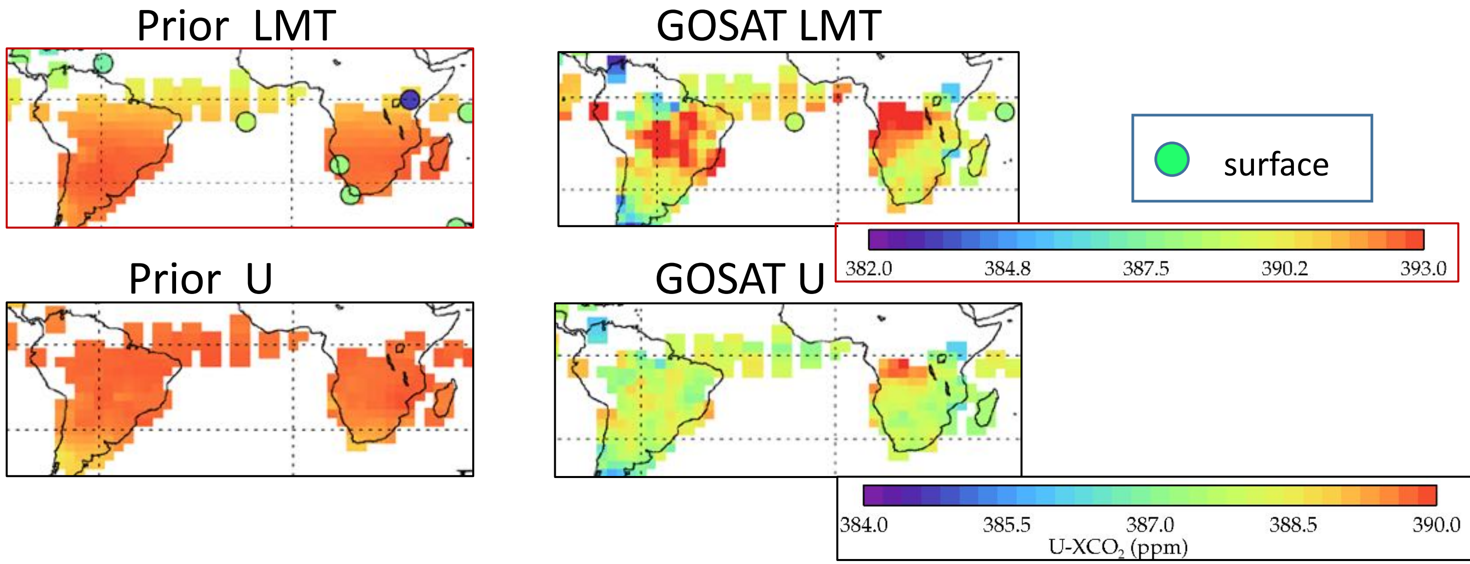
GOSAT U
(trop + strat)

GOSAT XCO_2

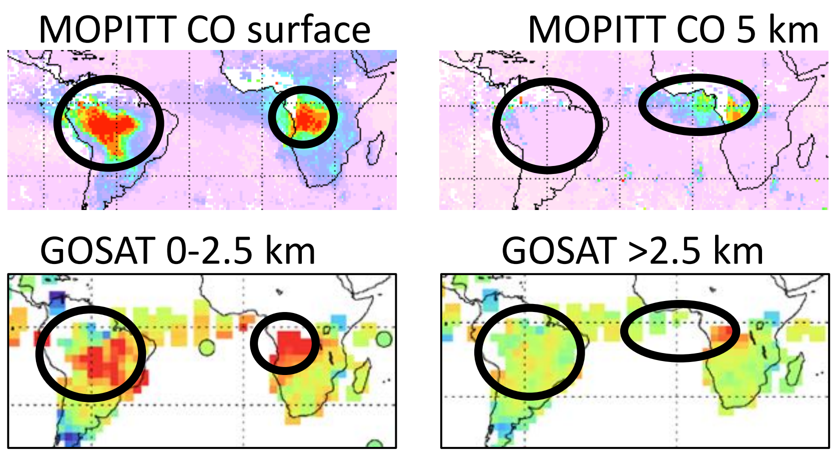




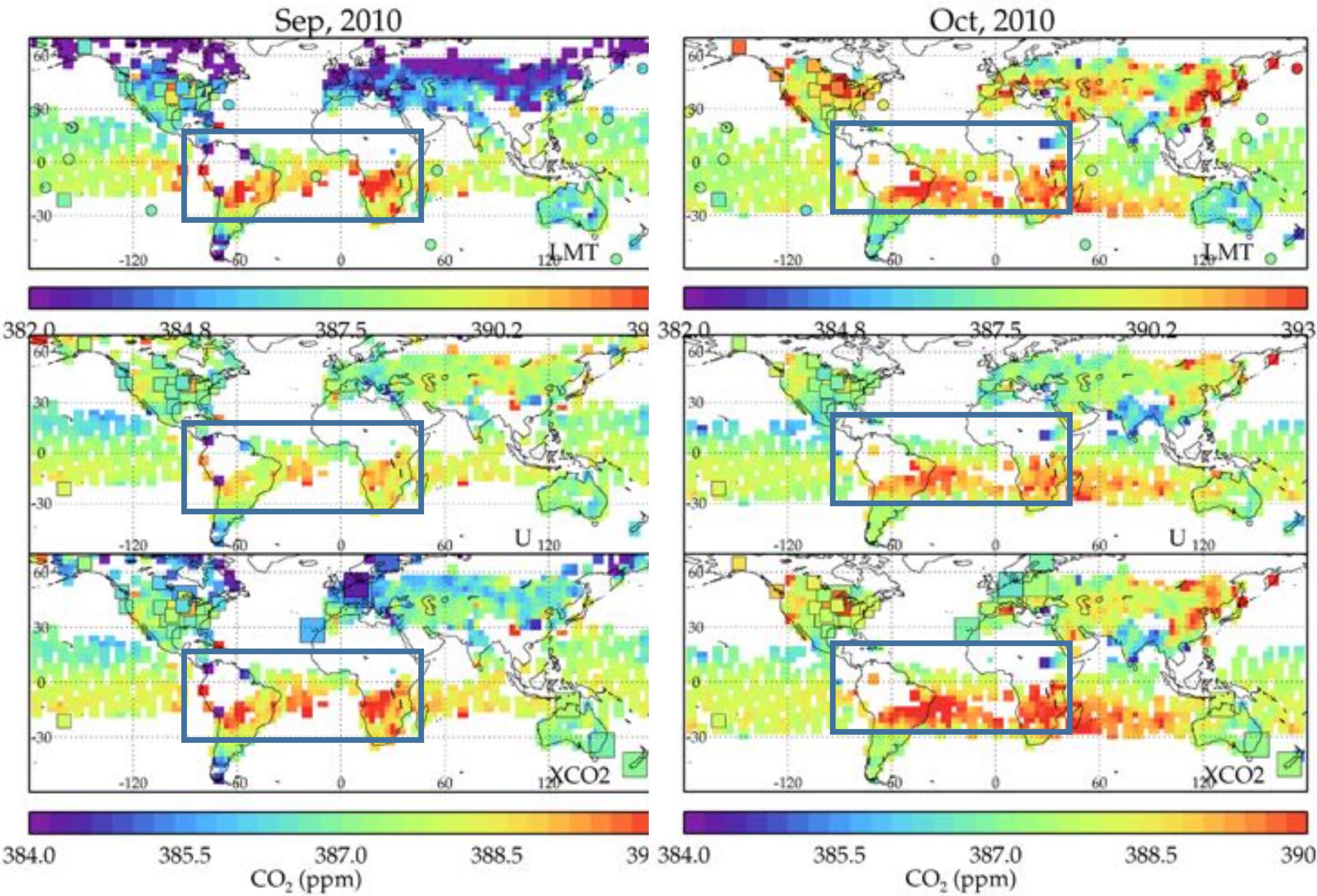
The signal is coming from the data, as the GOSAT prior is flat



A similar spatial and vertical pattern is seen in MOPITT multi-spectral CO retrievals:



The signal shows up in U in September and even more in October (in agreement with MOPITT)



Longitunal gradient in Europe/Asia

- Larger seasonal cycle in east Asia Observed in Lindqvist, 2015 (ACP); Kulawik, 2016 (AMT)

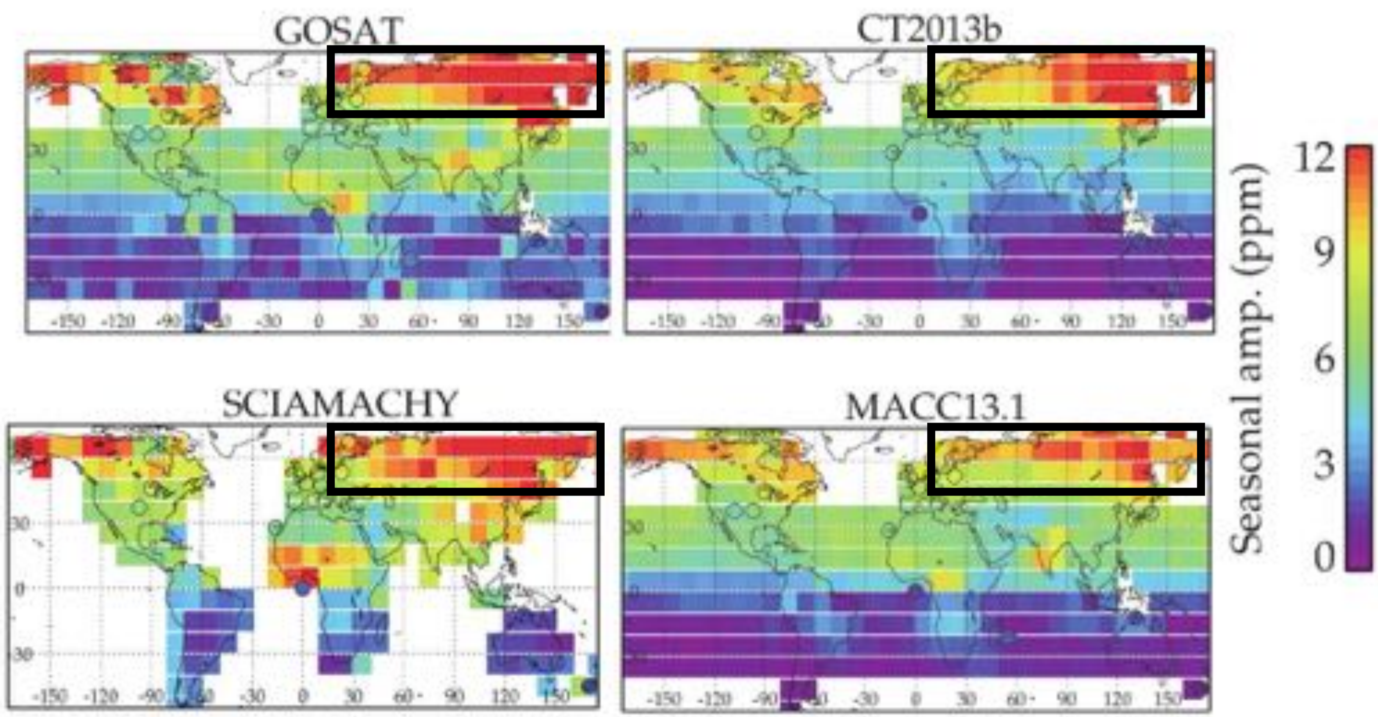
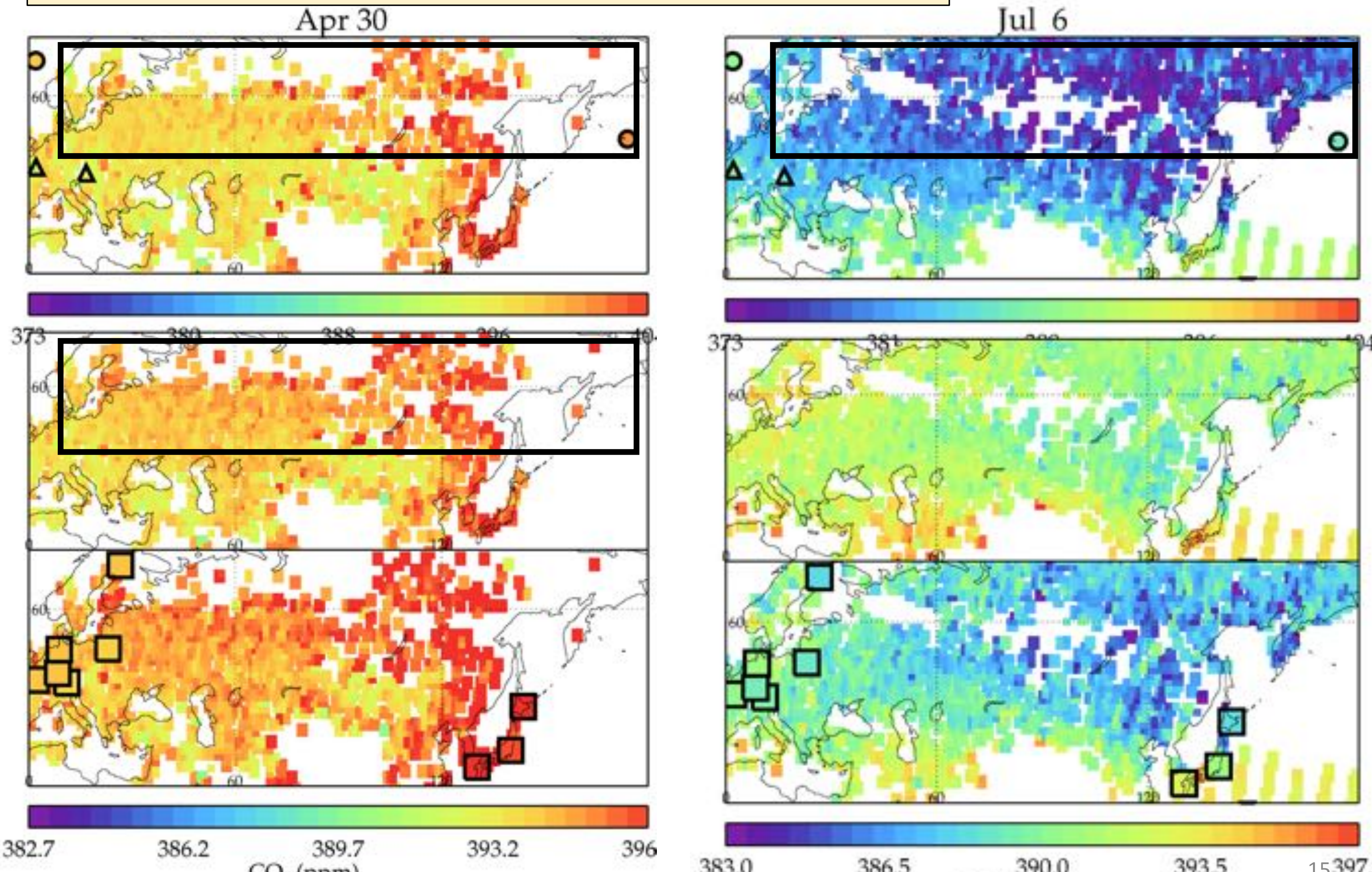


Figure 9, Kulawik, 2016

Gradients seen in LMT in BOTH peak and trough
Gradients seen in U peak



1 month average centered around date, averaged all years

Conclusions

- LMT error is $\sqrt{0.4^2 + 1.5^2/n}$ ppm for ocean, $\sqrt{1.5^2 + 3.0^2/n}$ ppm for land
- Modest improvement seen versus U.S. aircraft and larger improvements in non-US aircraft and remote surface sites
- LMT and U products see patterns consistent with MOPITT CO in SH biomass burning despite flat GOSAT prior
- Talk to me if you are interested in collaborating on use of these products!

Funded by NASA

Aircraft data citation

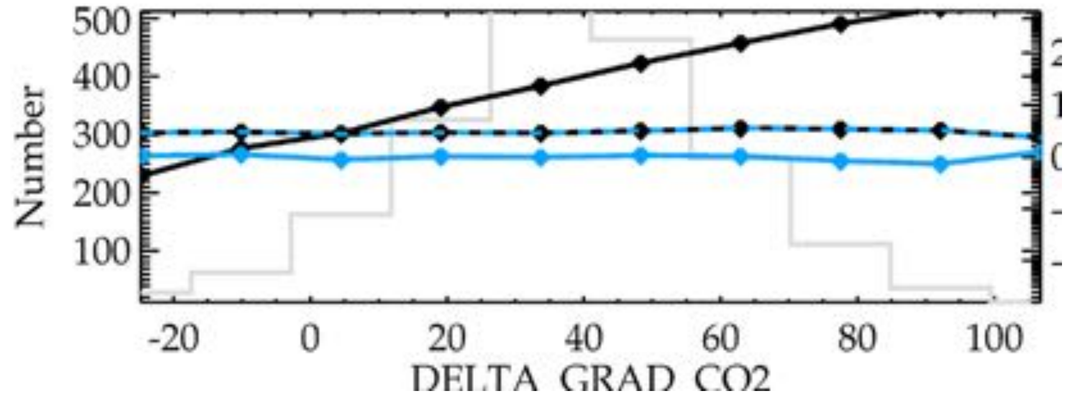
Bakwin, P.S., Conway, T.J., Dlugokencky, E.J., Guenther, D.W., Kitzis, D, Lang, P.M., Masarie, K.A., Novelli, P.C., Thoning, K.W., Tans, P.P., and Waterman, L.S., in Climate Monitoring and Diagnostics Laboratory GMD NO. 22 Summary Report 1994, edited by J.T. Peterson and R.M. Rosson, pp 18-30, US Department of Commerce, NOAA, Boulder, Colorado, 1994.

obspack_name : obspack_co2_1_PROTOTYPE_v1.0.4b_2014-02-13

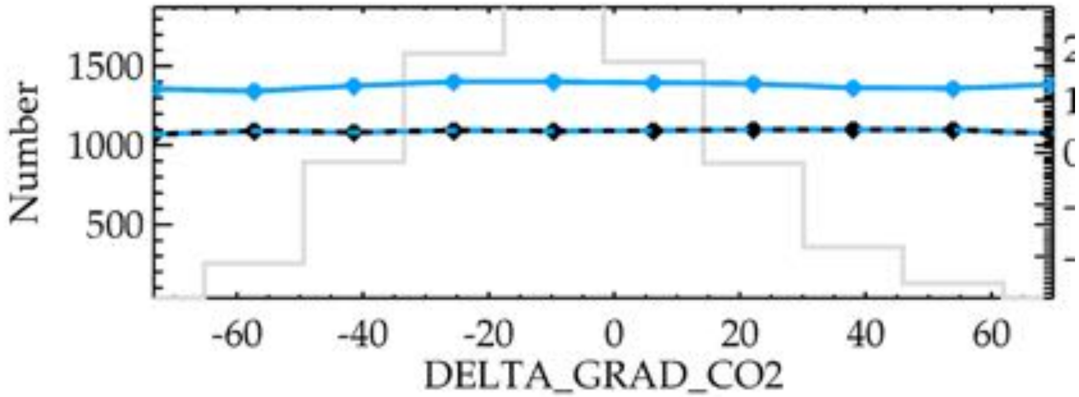
Bias correction

The original product has large and variable biases

~10% of gradient is flattened out by this correction



After correction



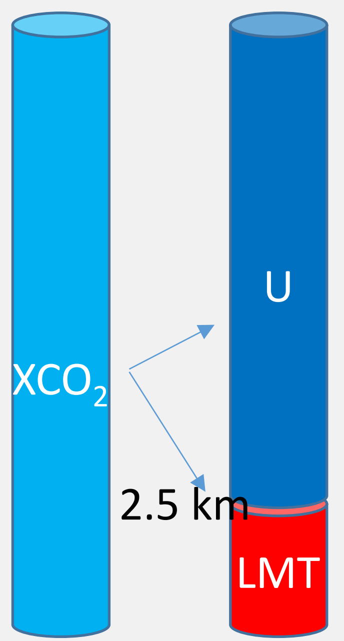
Room for further improvement but further corrections led to mixed results.

Impact on assimilation

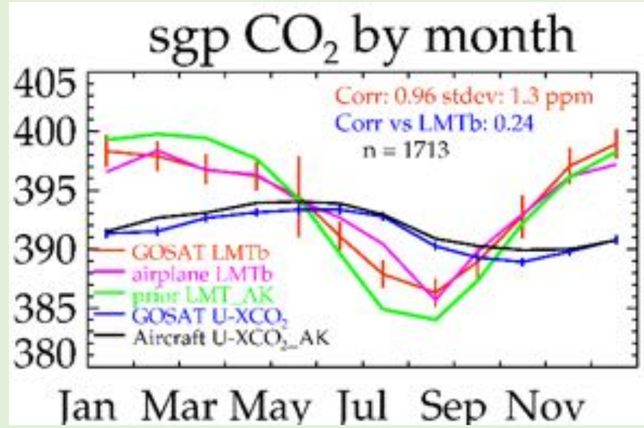
- Sensitivity to the entire boundary layer removes a major source of assimilation error, the boundary layer height (Denning et al., 1996; Gurney et al., 2002)
- Closer to the surface means less dependence on model transport
- Joint assimilation of products sensitive to the boundary layer and free troposphere constrains a major error source of partitioning between the NH and SH (Stephens, 2007)

- Assimilation study started by Feng Deng (Dylan Jones)

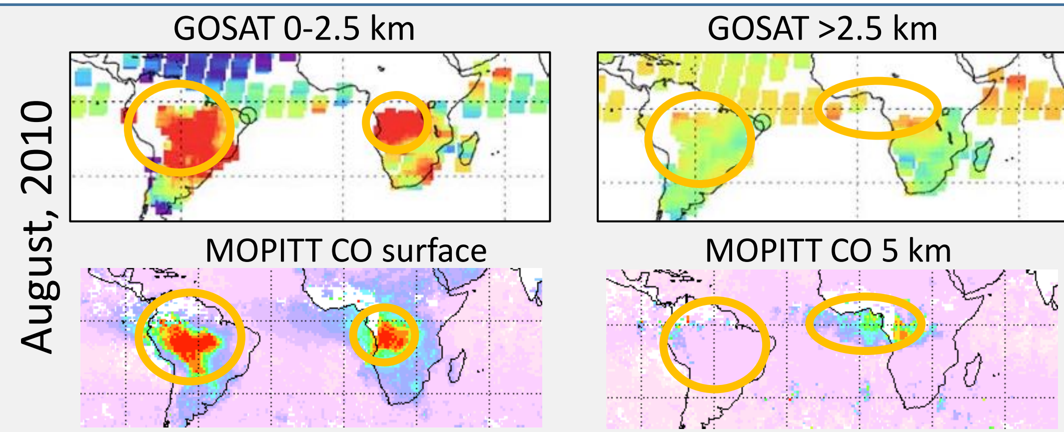
Lower tropospheric GOSAT (LMT-XCO_2)



The full-profile ACOS-GOSAT retrievals plus bias correction of O'Dell (2011) is used to create two partial columns, LMT and U. The same process should apply to OCO-2



Retrieved LMT (red) improves over the prior (green) versus aircraft (pink) at SGP



MOPITT multi-spectral CO is used to validate the partitioning between LMT-XCO2 and U-XCO2 in the tropics where the GOSAT prior is ~constant. High values are seen at the surface in South America in both GOSAT and MOPITT with outflow showing up in the free trop in later months (not shown).

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Work was performed under a cooperative agreement with NASA.
ACOS-GOSAT v3.5. MOPITT v6 TIR/NIR. Aircraft data citation: Bakwin, P.S. et al., 1994, obspack_co2_1_PROTOTYPE_v1.0.4b_2014-02-13