Three-dimensional distribution of greenhouse gas concentrations over megacities observed by GOSAT

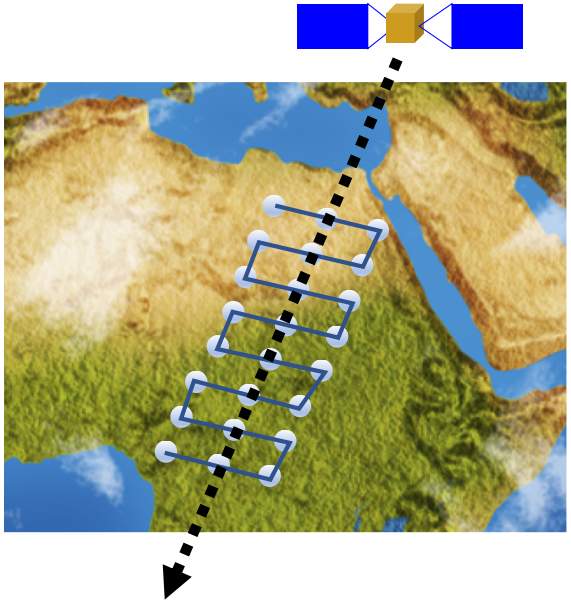
N. Kikuchi[1], A. Kuze[1], K. Kataoka[2], K. Shiomi[1], M. Hashimoto[1], H. Suto[1], R. Knuteson[3], L. Iraci[4], E. Yates[4], W. Gore[4], and T. Tanaka[4]

1. Japan Aerospace Exploration Agency
2. Remote Sensing Technology Center of Japan
3. University of Wisconsin
4. NASA/Ames Research Center

Contents

- GOSAT target mode observations of megacities
- GHG concentrations retrieved from simultaneous measurement of SWIR and TIR
- Rough estimate of GHG flux from megacities

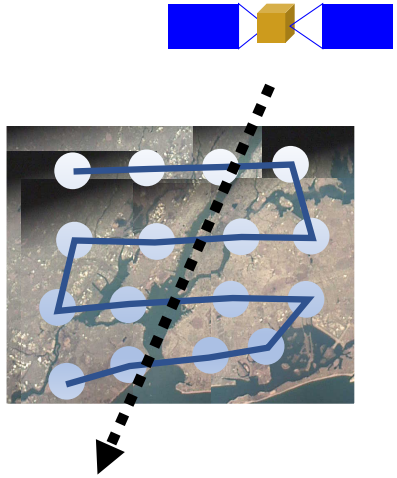
Regular grid observations
(since launch in 2009~)



GHG flux down to 1000 km scale

+

Extensive target mode observations
of megacities (2016~)

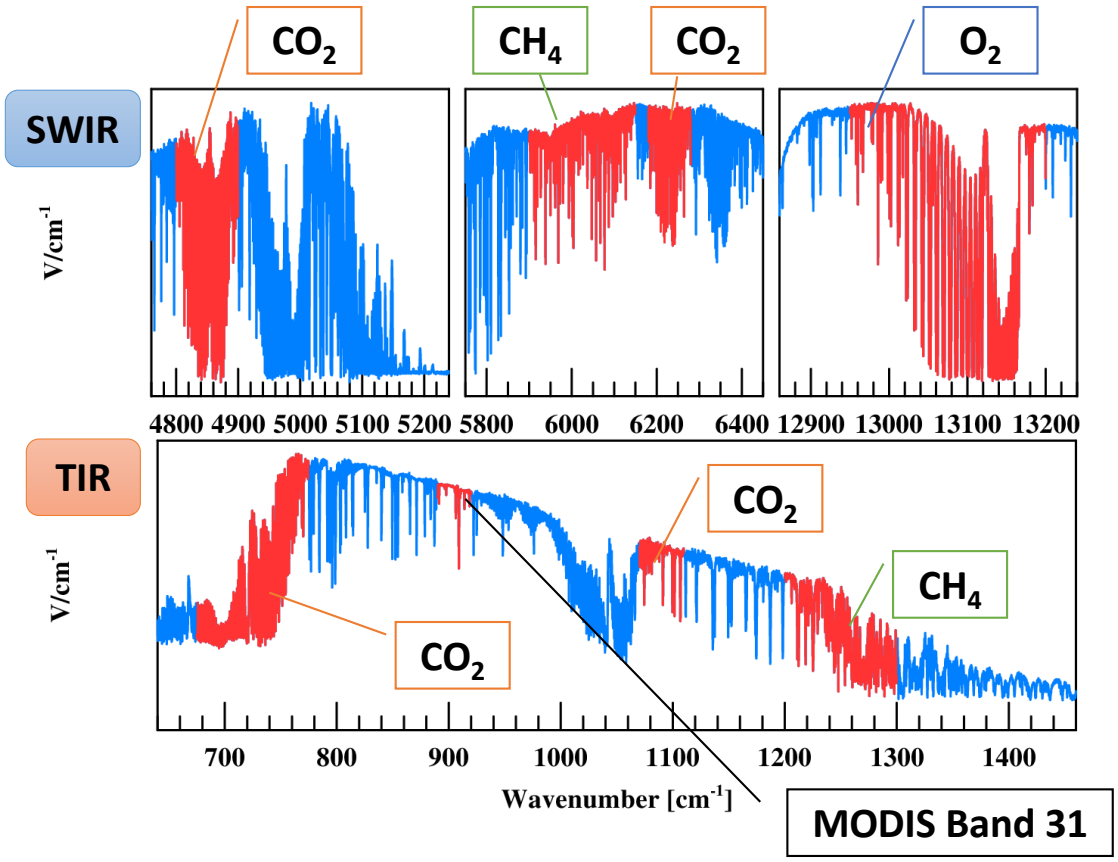


TANSO-FTS
- Pointing mechanism
- SWIR+TIR

→ 3D distribution of GHG concentrations

GHG flux from megacities
Feasible?

GOSAT TANSO-FTS spectral coverage



- Adding TIR windows increases information on vertical structure.
- Independent estimate of the two-layer concentrations of CO_2 and CH_4.

- Co-location of SWIR and TIR is exact.
- Applicable to large emission events/sources

Retrieval algorithm for GHG concentration

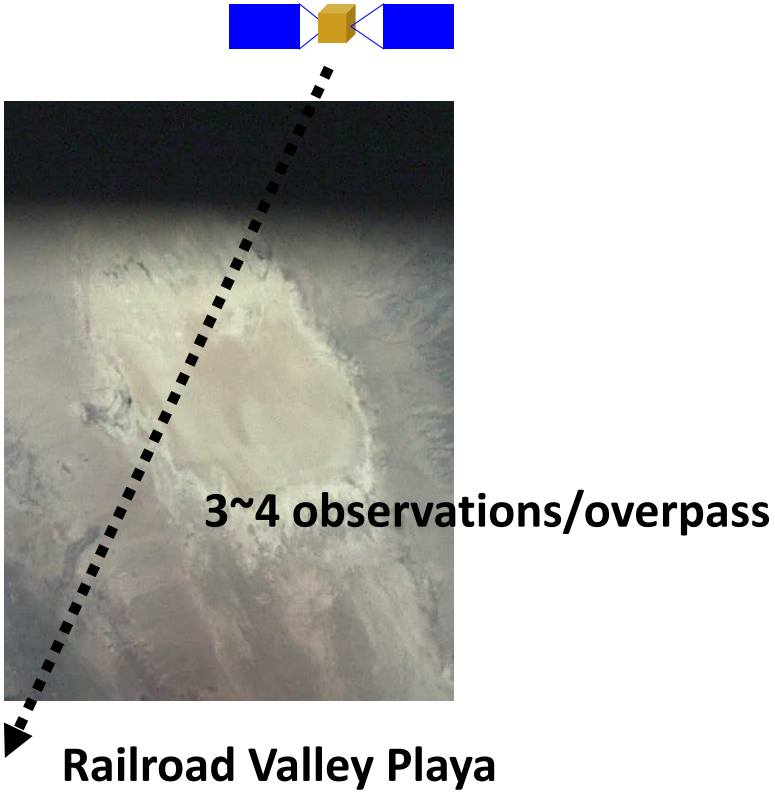
- Adding a TIR module to the existing SWIR algorithm of Kikuchi et al. (2016)
- A Maximum A posteriori solution is obtained by minimizing the cost function:

$$J(x) = [y - F(x)]^T S_\varepsilon^{-1} [y - F(x)] + (x - x_a)^T S_a^{-1} (x - x_a)$$

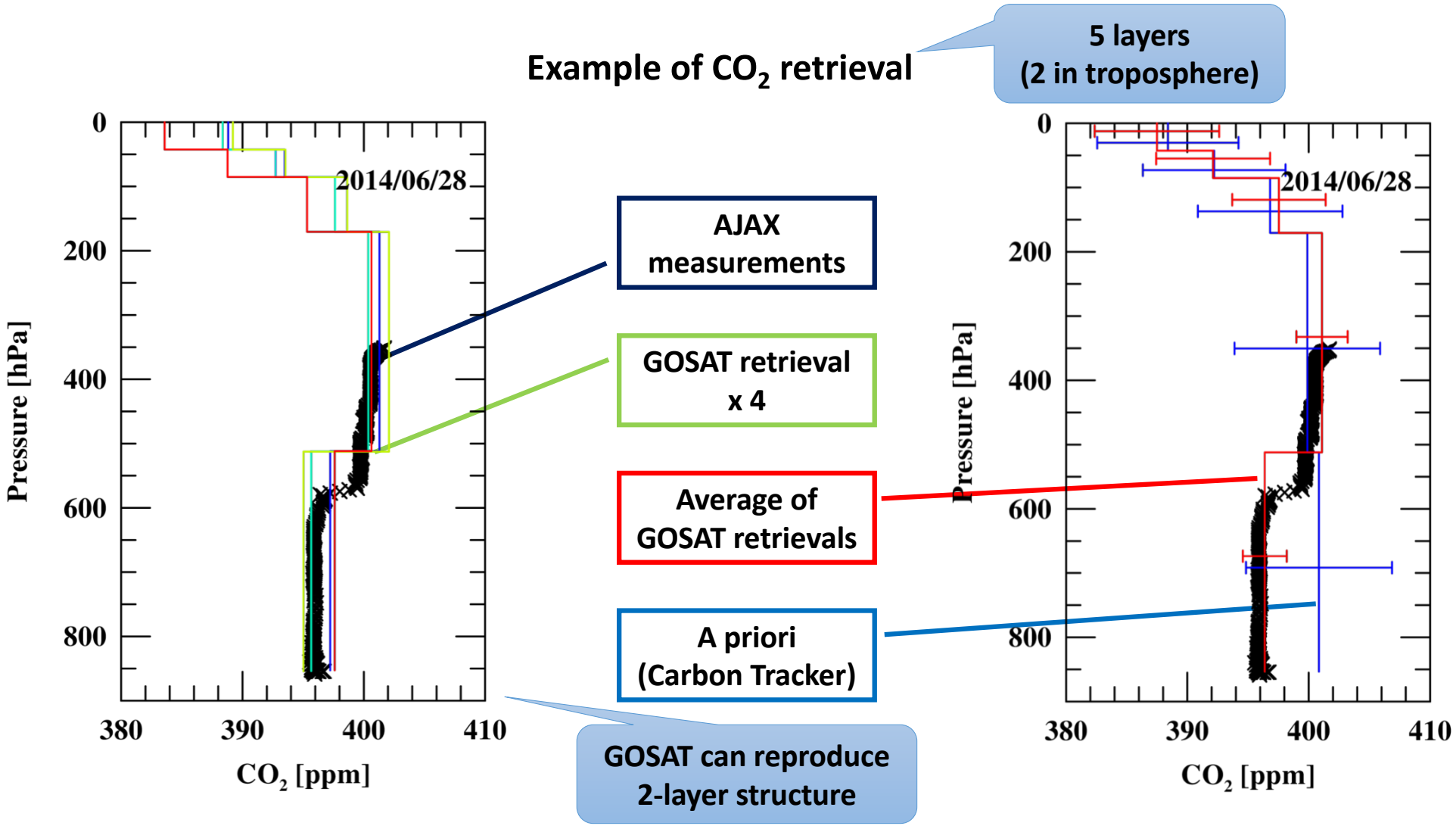
y	Measurement vector (SWIR + TIR spectra)
x	State vector (GHG concentrations etc.)
$F(x)$	Forward model
S_ε^{-1}	Covariance of measurements noise
x_a	Prior estimate
S_a^{-1}	Covariance of prior estimate

Test against in situ airborne data over Railroad Valley Playa

- RRV is the vicarious calibration site of GOSAT since 2009.
- In situ measurement data are available.
  - Temperature and water vapor by radiosonde
  - Vertical profiles of CO_2 and CH_4 concentrations by Alpha Jet Atmospheric eXperiment (AJAX)
- We used 10 AJAX flight data (36 GOSAT observations).



Example of CO_2 retrieval

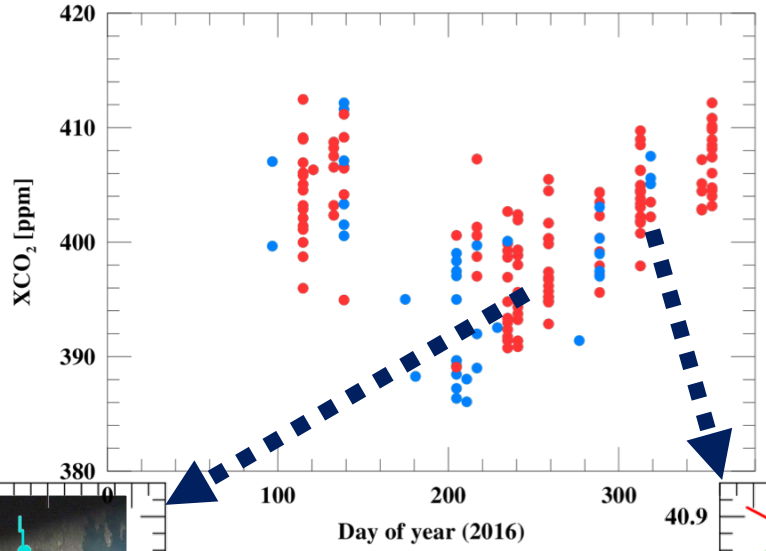


CO_2 in New York

CO_2 increase

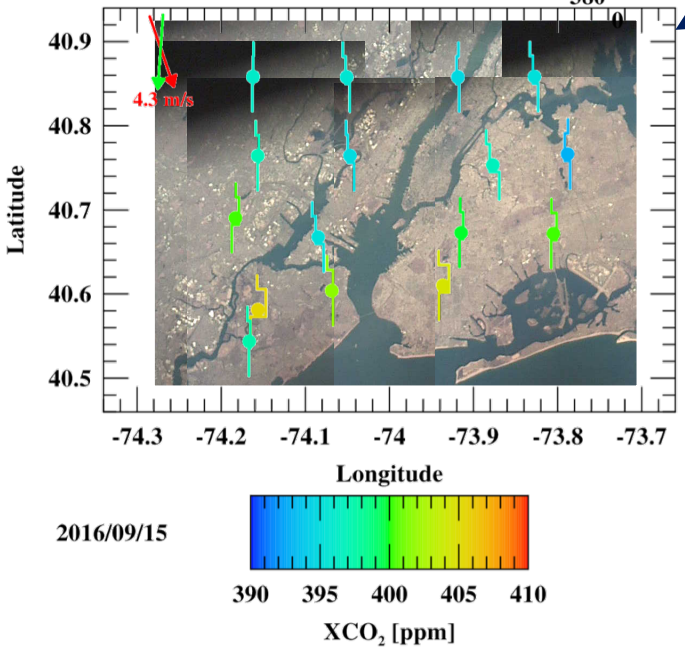
Wind

Summer depletion
Flat vertical profile



- Clear sky
- Cloud contamination (judged by the onboard camera image)

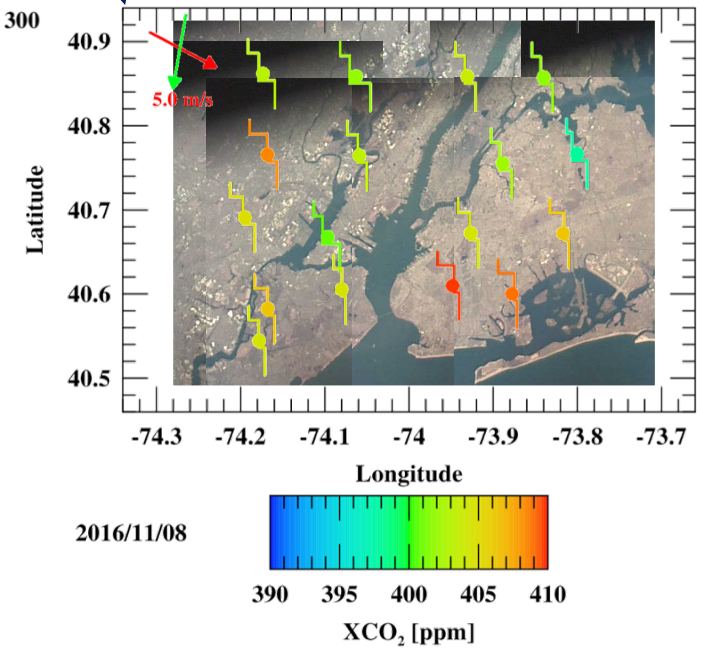
Winter enhancement
High CO_2 in lower troposphere



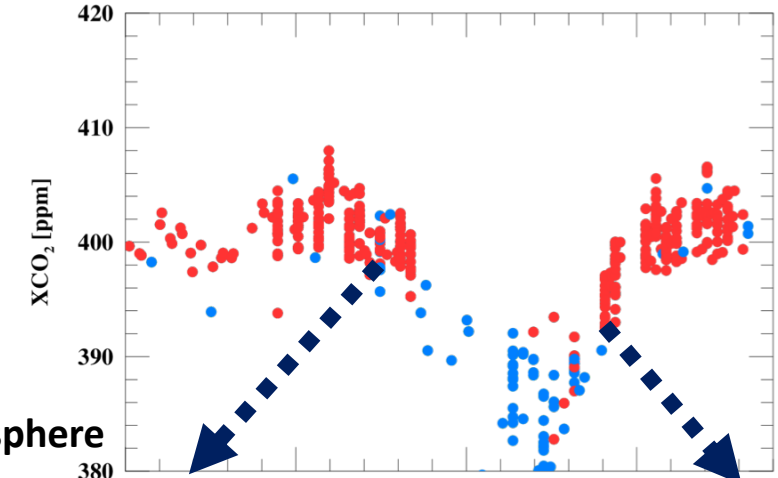
Observation location

vertical profile

Color indicates column-averaged concentration



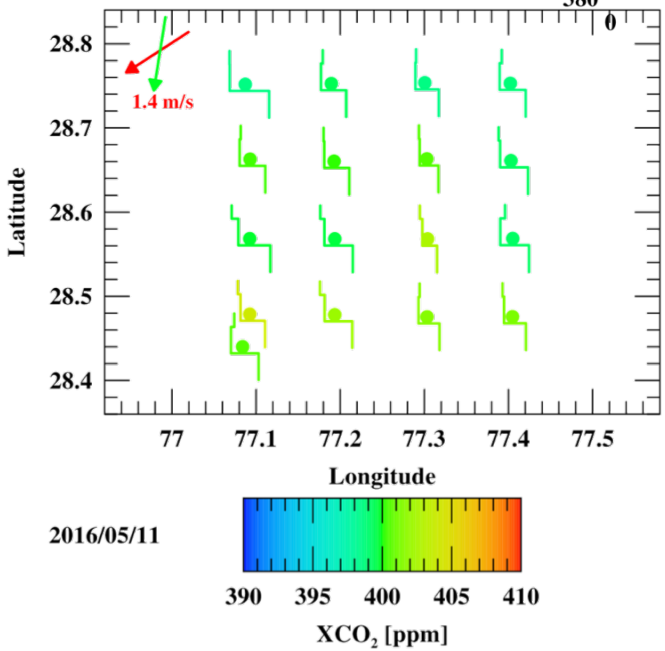
CO_2 in Delhi



- Clear sky
- Cloud contamination (judged by the onboard camera image)

Dry season
High CO_2 in lower troposphere

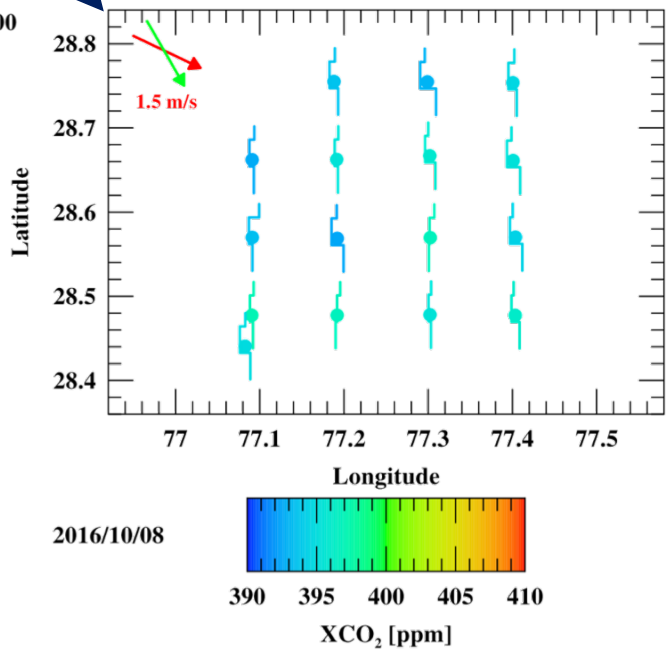
(end of) Rainy season
Flat vertical profile



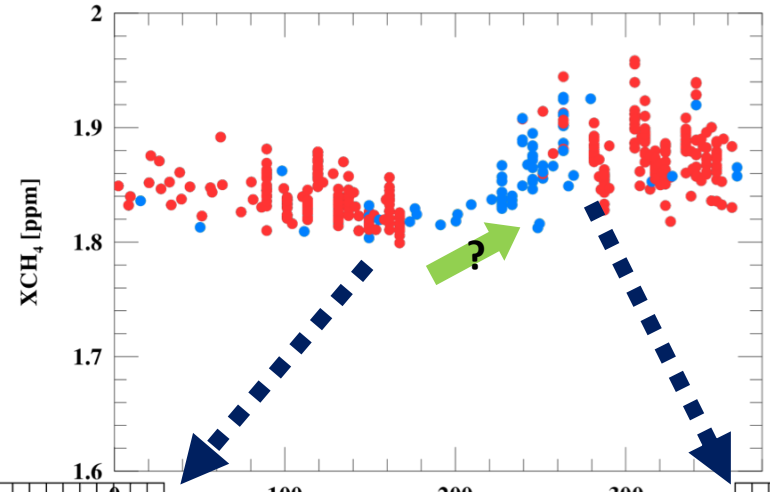
Observation location

vertical profile

Color indicates column-averaged concentration

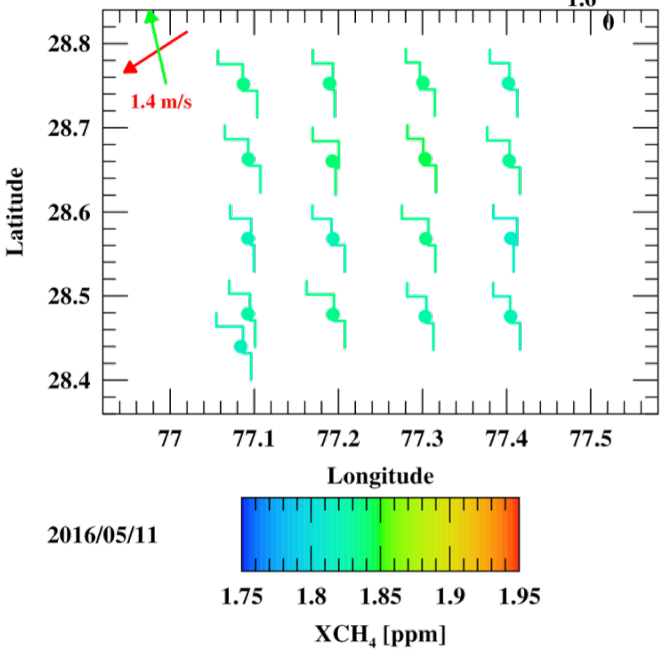


CH_4 in Delhi

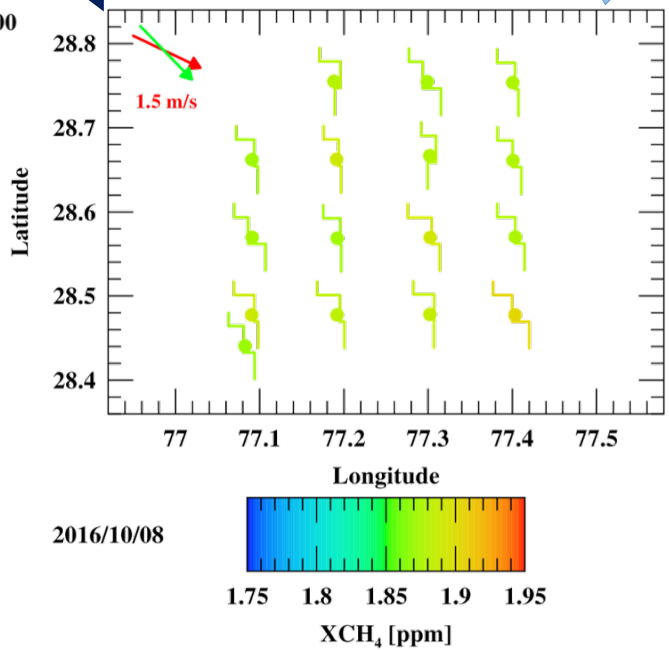


CH_4 increases in the lower troposphere along the wind direction←surface flux?

Dry season



(end of) Rainy season



Observation location

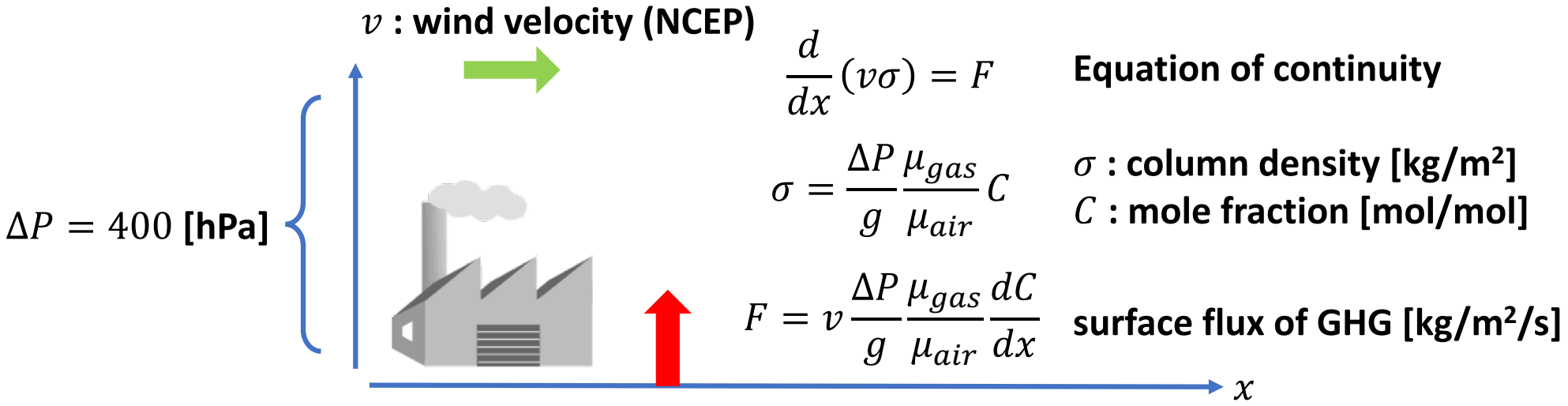
vertical profile

Color indicates column-averaged concentration

Rough estimate of GHG flux from megacities using a simple 1D steady model

Assumptions:

- **Surface flux is uniform within a city.**
- **Wind velocity is constant.**
- **Steady state**



$$\frac{d}{dx}(v\sigma) = F$$ **Equation of continuity**

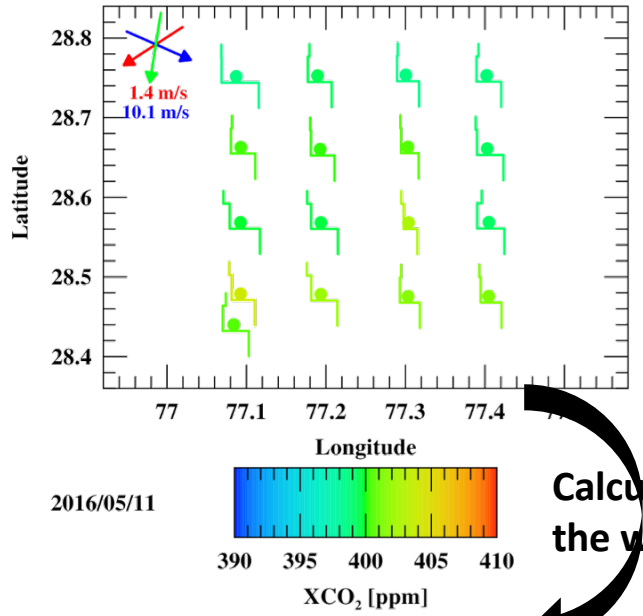
$$\sigma = \frac{\Delta P}{g}\frac{\mu_{gas}}{\mu_{air}}C$$ σ **: column density [kg/m²]**

C **: mole fraction [mol/mol]**

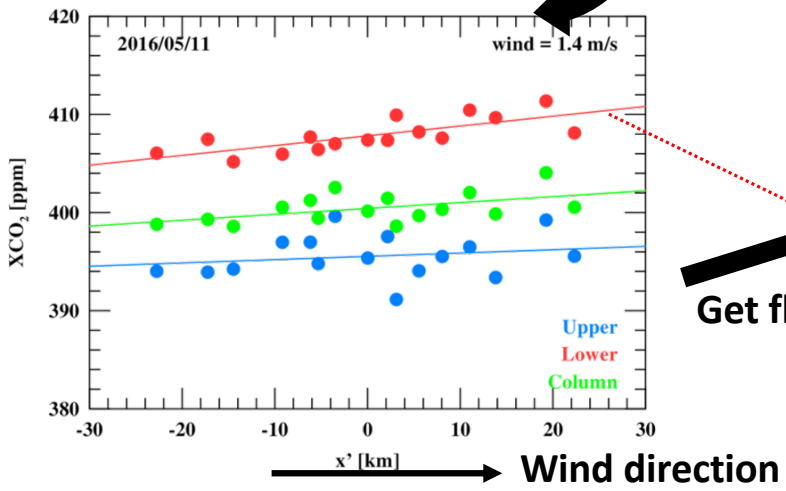
$$F = v\frac{\Delta P}{g}\frac{\mu_{gas}}{\mu_{air}}\frac{dC}{dx}$$ **surface flux of GHG [kg/m²/s]**

CO_2 flux in Delhi

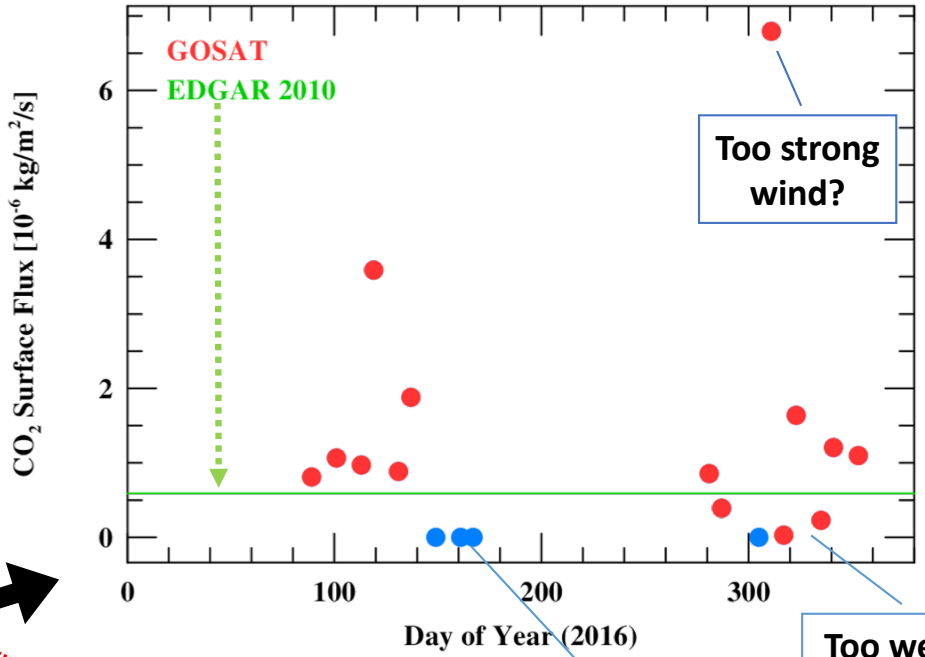
Except for some outliers, GOSAT observations are comparable with inventory (EDGAR v 4.2).



Calculate slope in the wind direction



Wind direction



Too strong wind?

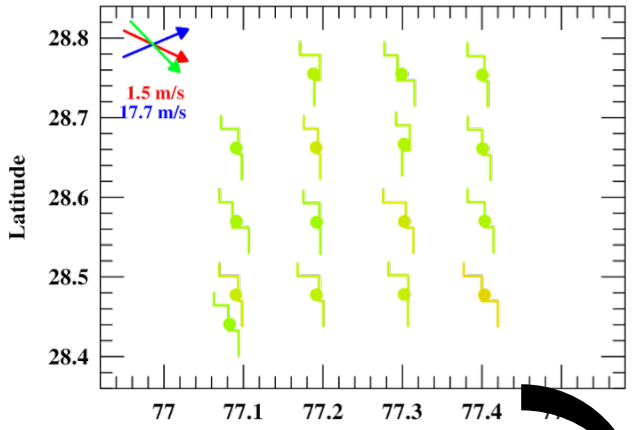
Too weak wind?

Failed to get positive flux

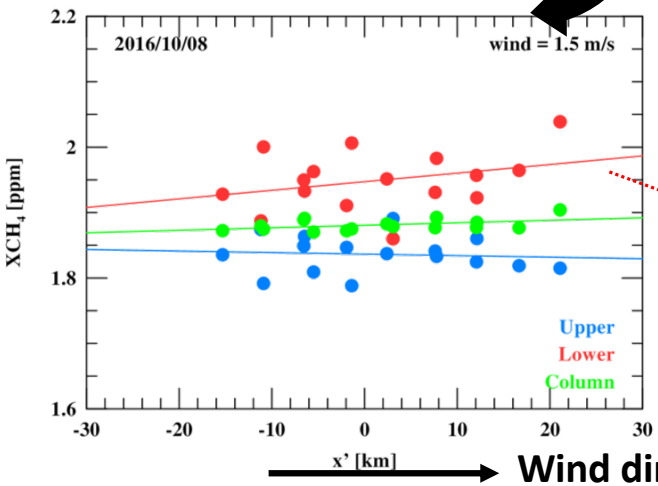
Get flux from the slope and the wind velocity

$$F \propto v\frac{dC}{dx}$$

CH_4 flux in Delhi



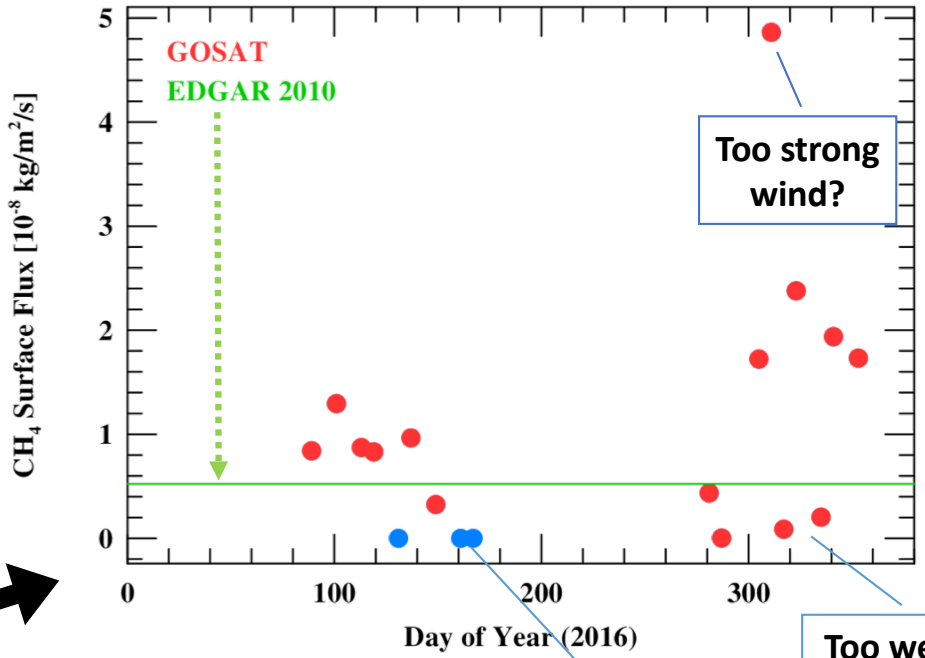
Calculate slope in the wind direction



Wind direction

Get flux from the slope and the wind velocity

$$F \propto v\frac{dC}{dx}$$



Too strong wind?

Too weak wind?

Failed to get positive flux

Summary

- **GOSAT is extensively observing ~20 megacities since 2016.**
  Visit JAXA/EORC website for a complete list of the target cities:
  http://www.eorc.jaxa.jp/GOSAT/CO2_monitor/index.html

- **TANSO-FTS can reproduce the two-layer vertical structure of GHG measured by the airplane experiment AJAX.**

- **TANSO-FTS can capture the seasonal variation in vertical structure of GHG over megacities.**

- **GHG flux derived from a simple model is comparable with inventory.**
  More realistic model could improve accuracy of GHG flux.

Acknowledgements

- H. Tran ... gas absorption tables for CO_2
- G. C. Toon ... Solar spectral irradiance
- NIES GOSAT project office ... SPRINTARS data for prior estimates of aerosols

Thank you for your kind attention.