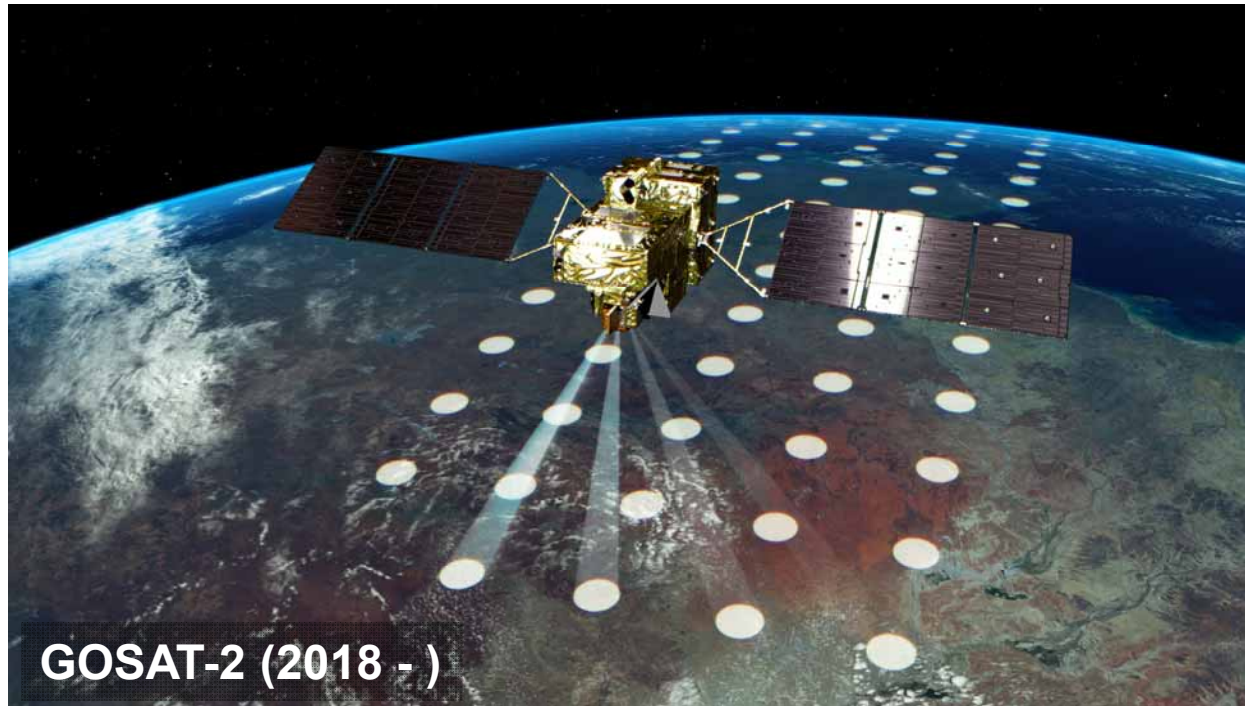




How to Use Satellite GHG Concentration Data for Verification of GHG Emissions Inventories



Dr. Tsuneo Matsunaga
Satellite Observation Center
National Institute for Environmental Studies, Japan

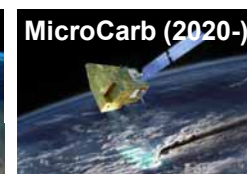
Take-home Messages



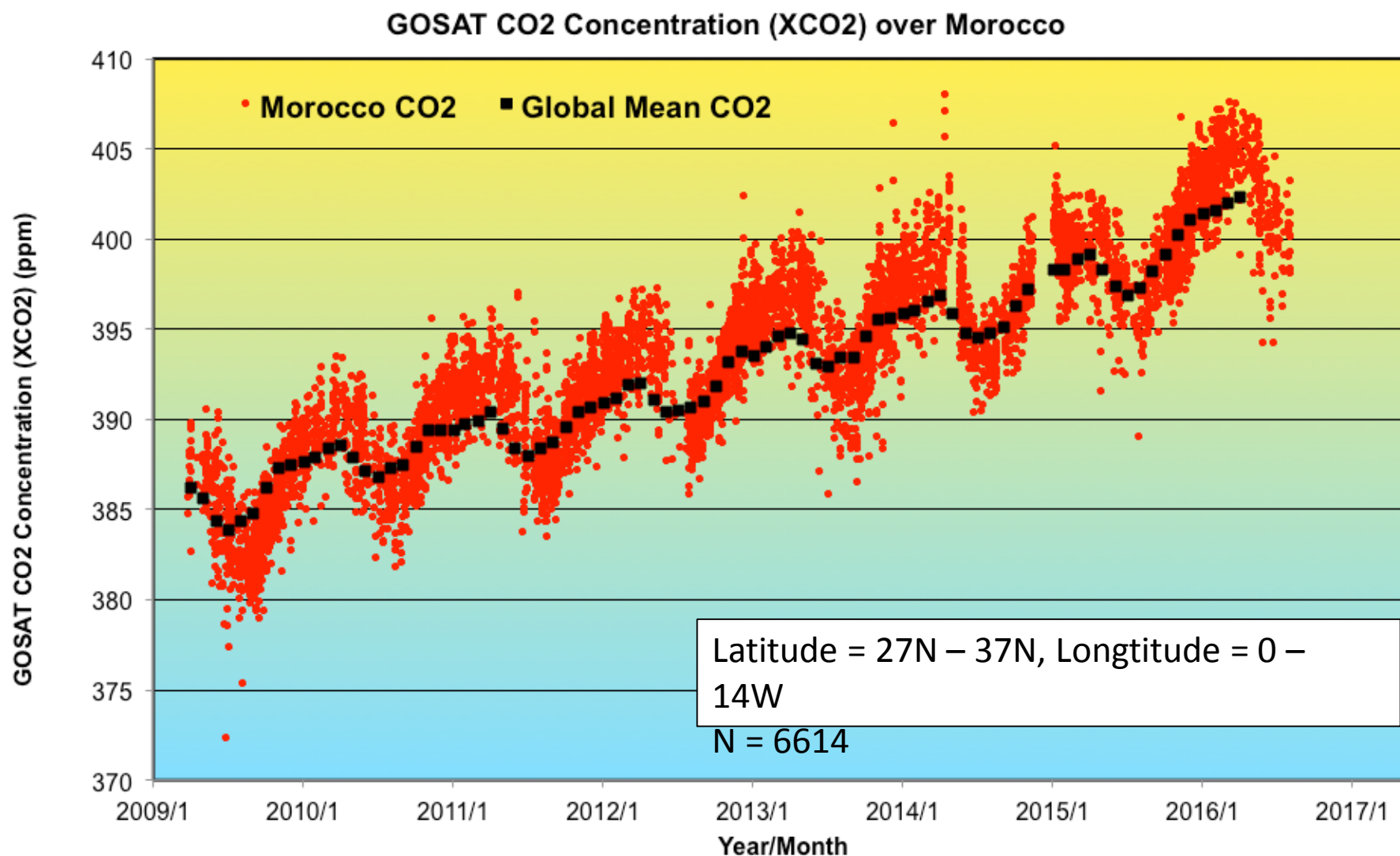
- ✓ We have satellite GHG data for more than 10 years. New satellites are going to be launched in coming years. **Data gaps will be avoided.**
- ✓ Peer-reviewed papers regarding satellite – inventory comparison are being published. **Methodologies are not matured yet but promising.**
- ✓ It is high time to start discussion on how to use satellites to **verify GHG emission inventories.**

Satellites for Greenhouse Gases Observation

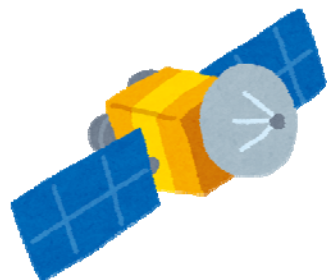
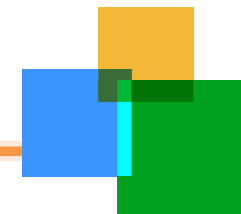
Mission	Country	Period	GHGs	
SCIAMACHY (ENVISAT)	(ESA)	2002 -2014	CO2, CH4	
GOSAT	Japan	2009 -	CO2, CH4	
OCO-2	US	2014 -	CO2	
TanSat	China	2016 -	CO2	
GOSAT-2	Japan	2018 -	CO2, CH4	
OCO-3	US	2018 -	CO2	ISS
MERLIN	France/ Germany	2019 -	CH4	Laser
MicroCarb	France	2020 -	CO2	



Morocco CO₂ Concentration by GOSAT

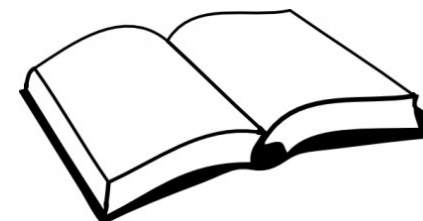
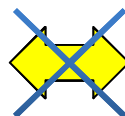


How to Compare Satellite and Inventory (1)



Satellite

GHG atmospheric concentration
Example : CO₂ = 400 ppm



Inventory

GHG emission (flux) into atmosphere
Example : CO₂ = 36 Gt CO₂ per year

GHG Flux derived from satellite
GHG concentration and
atmospheric transport model



(Flux-based Method)

Inventory

GHG emission (flux) into atmosphere

(Concentration-based Method)

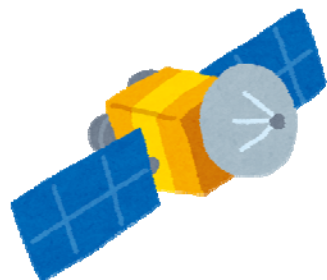
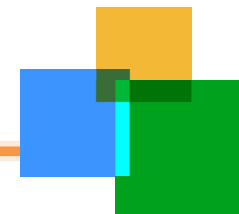
Satellite

GHG atmospheric concentration



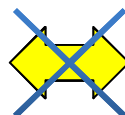
GHG Concentration derived from
inventory and
atmospheric transport model

How to Compare Satellite and Inventory (2)



Satellite

Sum of all sources and sinks



Inventory

Anthropogenic emission only

Satellite data after removal of contributions of biosphere, ocean, and so on



Inventory

Anthropogenic emission only

Satellite
Sum of all sources and sinks



Sum of anthropogenic emission and biospheric / ocean flux

Two Methods for Satellite / Inventory Comparison



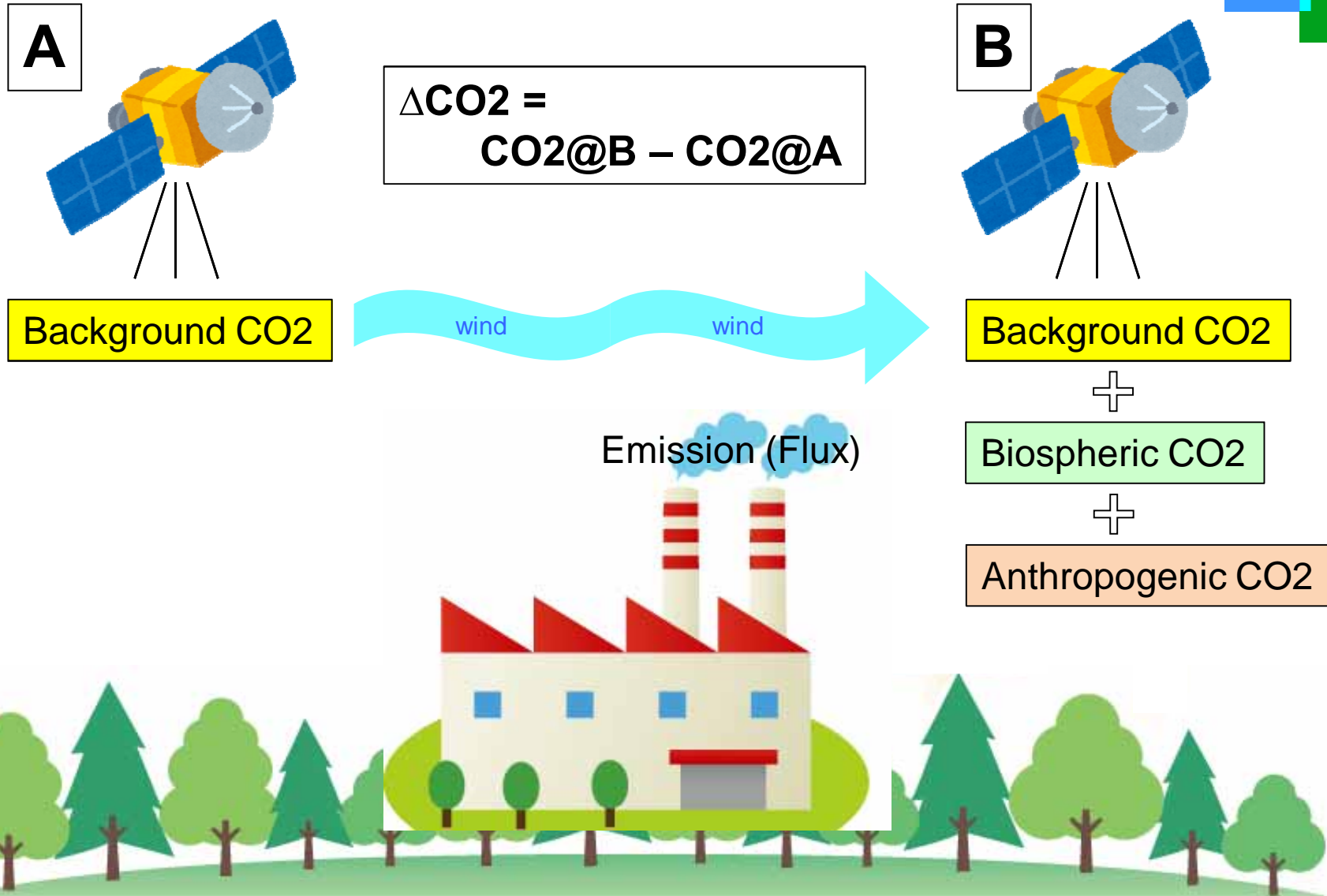
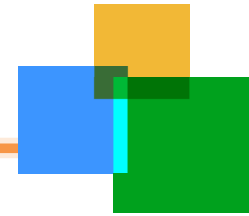
Flux-based Method

- Regional net flux can be obtained by inverse analysis using satellite data and atmospheric transport model (Backward) .
- This flux can be compared with the sum of anthropogenic emission (inventories) and natural source/sink flux data.

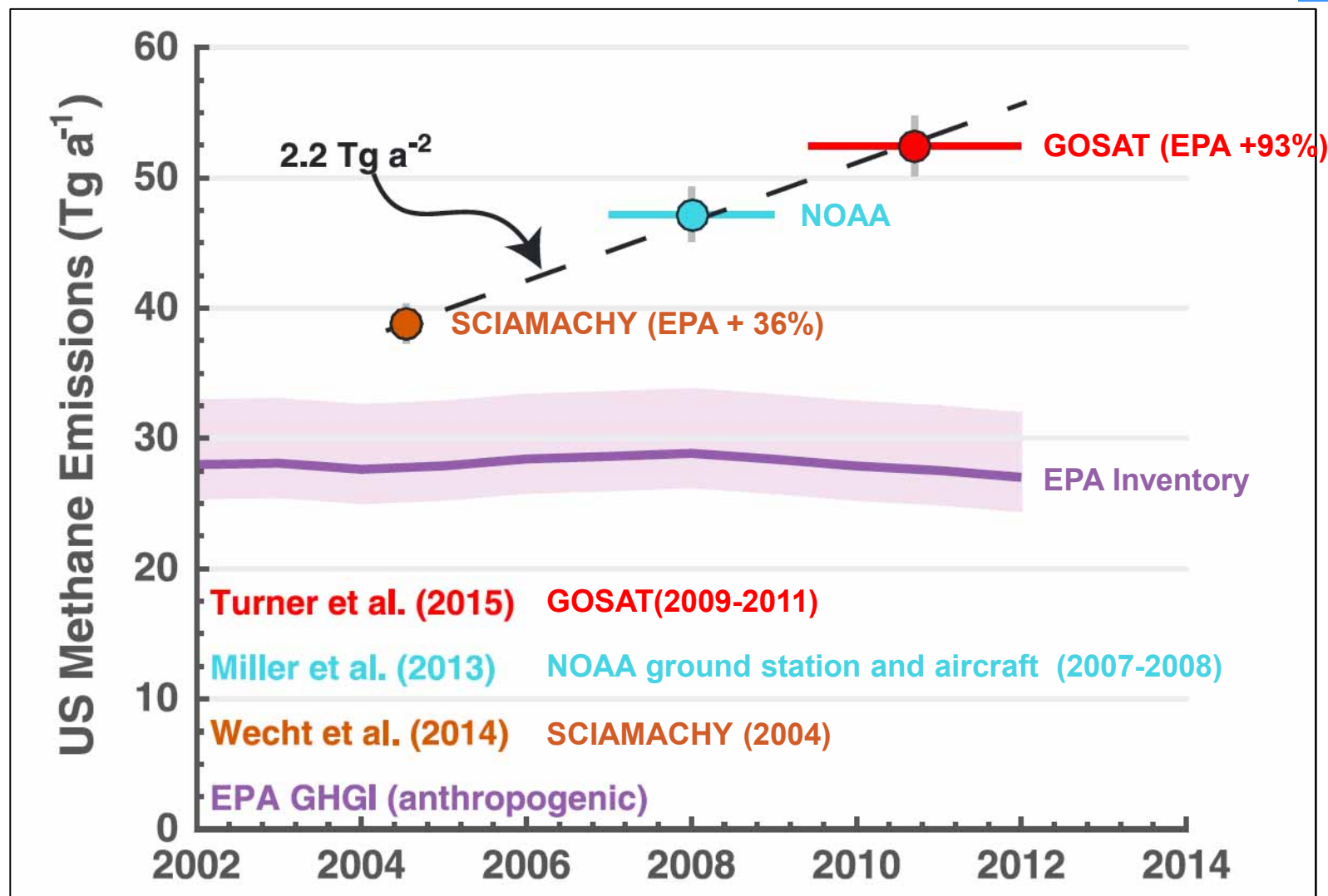
Concentration-based Method

- GHG concentration increase from background can be obtained from satellite data.
- This increase can be compared with anthropogenic GHG concentration which is calculated from emission inventories using atmospheric transport model (Forward).

Concentration-based Method : GHG Concentration Increase from Background

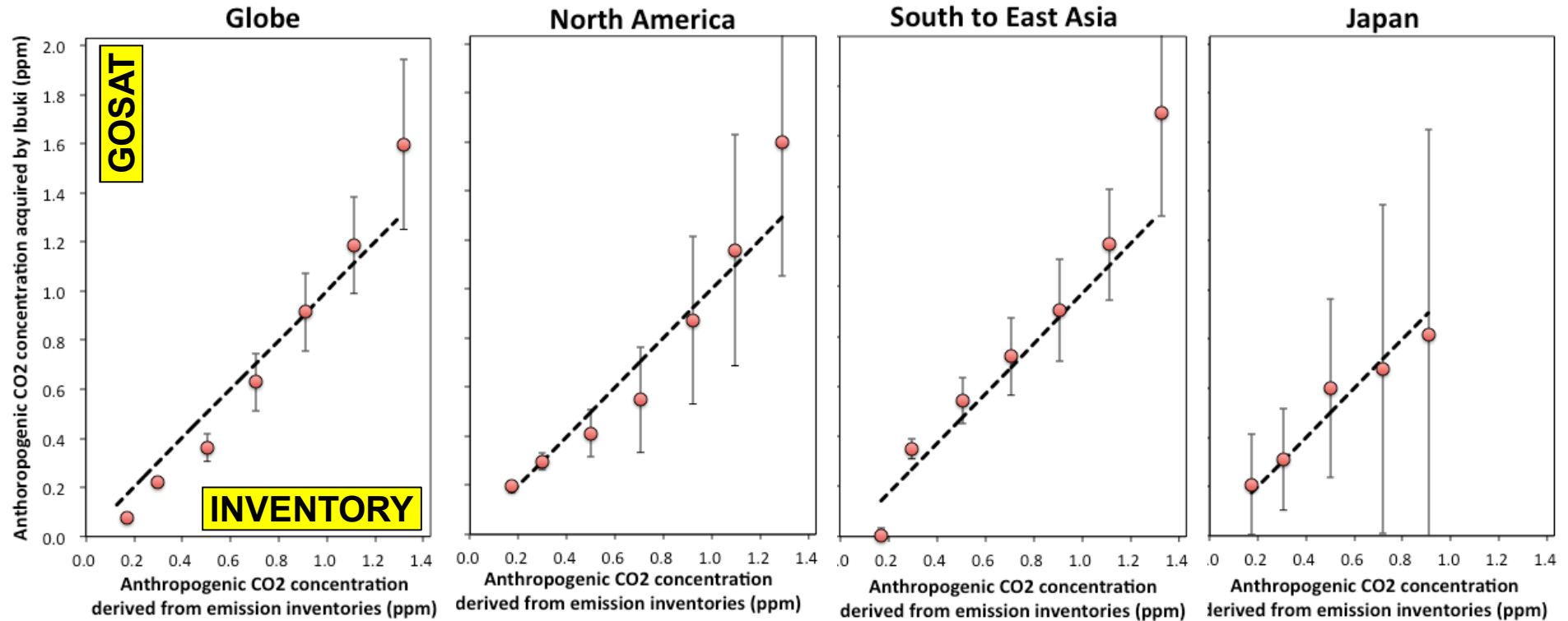


Flux-based method : CONUS Methane Emission Comparison



Turner et al. (2016)

Concentration-based Method : CO2 Emission Global / Country-scale Comparison



N = 13616

Regression Slope

1.08 ± 0.13

N = 4684

Regression Slope

0.99 ± 0.28

N = 5589

Regression Slope

0.99 ± 0.17

N = 396

Regression Slope

0.95 ± 0.79

Data = GOSAT (2009 – 2014). Method = Janardanan et al. (2016).

Remaning Issues



✓ The error bars for small regions are still large because the number of satellite GHG data is not enough yet.

⇒ Improvement of future satellites (Technical challenge)

⇒ Use of multiple satellites (Inter-satellite calibration)

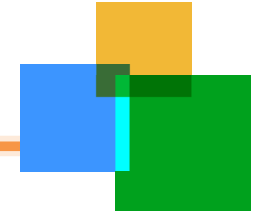
✓ Atmospheric transport models

- Accuracy
- Computation resources

✓ Other emission sources and sinks

- Terrestrial biosphere
- Fires

References (Recent peer-reviewed papers)



Flux-based Method

[Global and contiguous US][GOSAT]

Turner et al., Estimating global and North American methane emissions with high spatial resolution using GOSAT satellite, *Atmospheric Chemistry and Physics*, 2015

Turner et al., A large increase in U.S. methane emissions over the past decade inferred from satellite data and surface observations, *Geophysical Research Letters*, 2016

Concentration-based Method

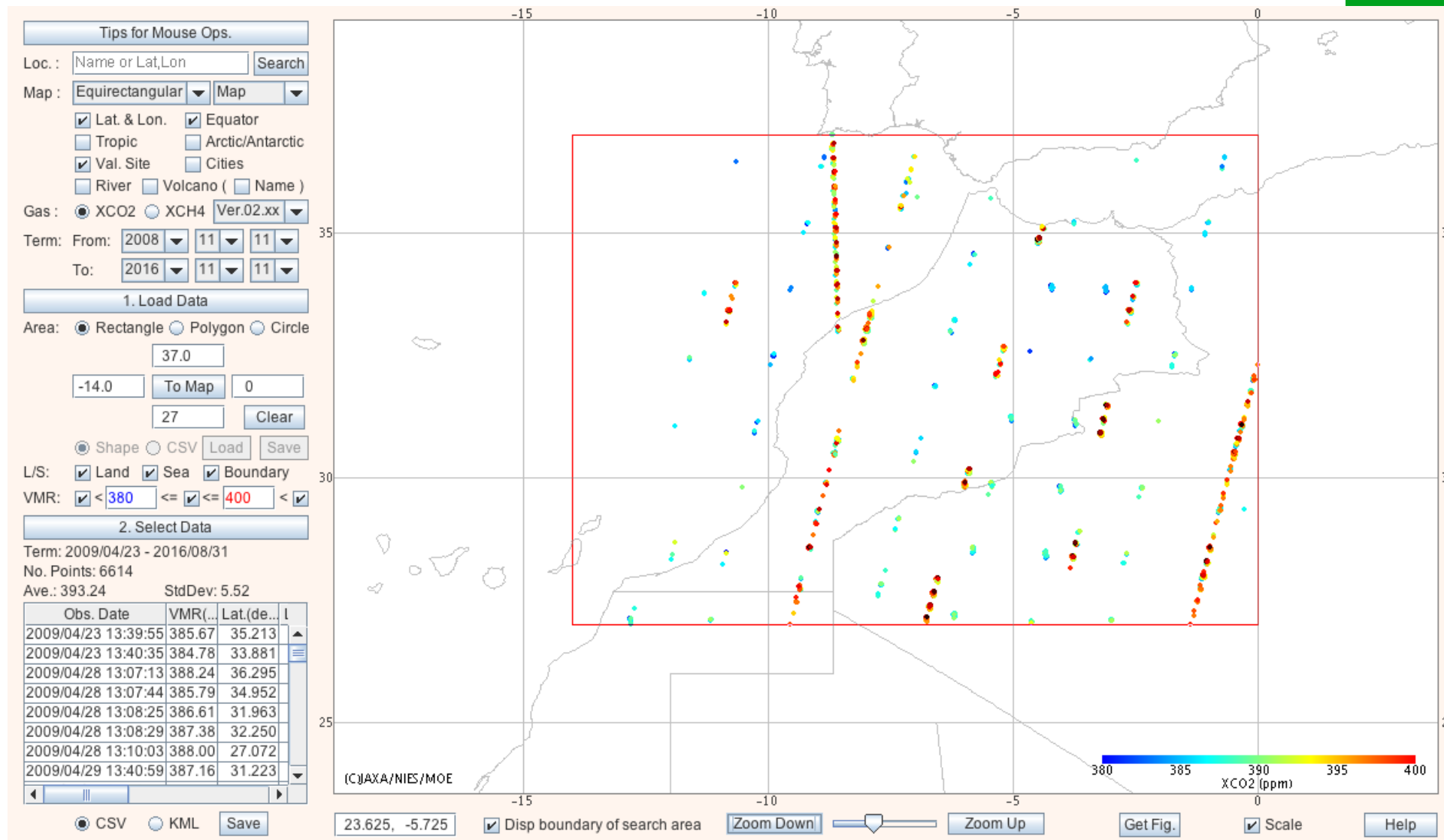
[Global, Asia, and North America][GOSAT]

Janardanan et al., Comparing GOSAT observations of localized CO₂ enhancements by large emitters with inventory-based estimates, *Geophysical Research Letters*, 2016.

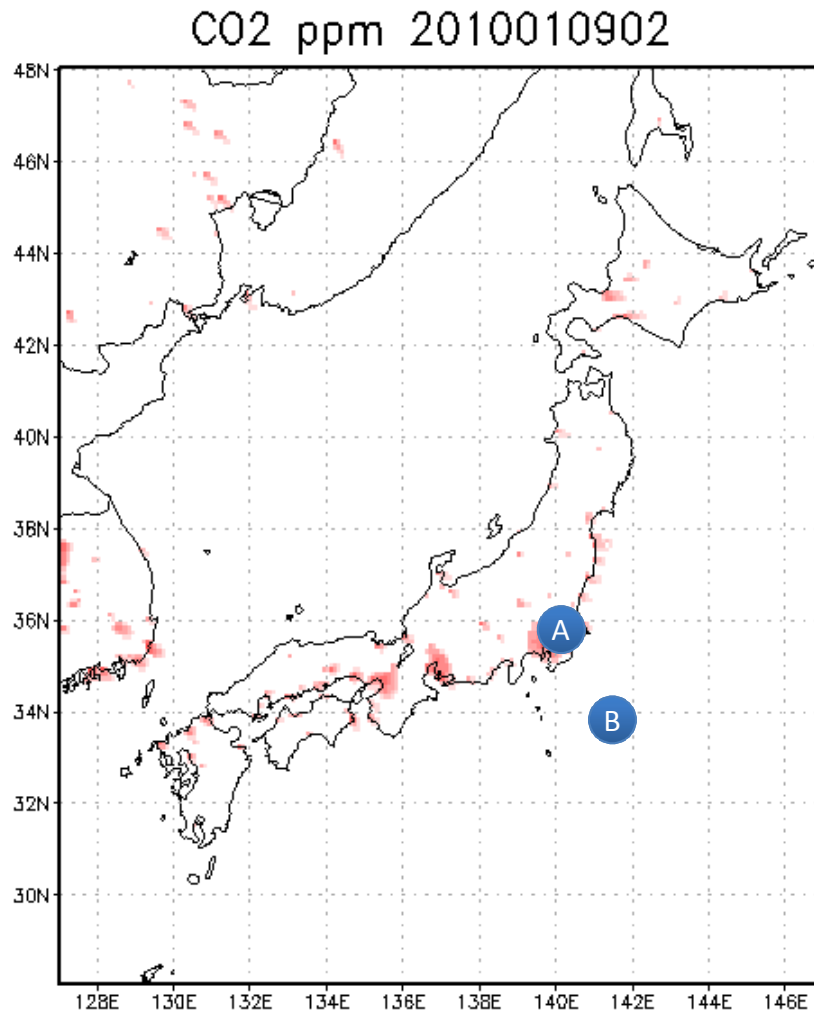
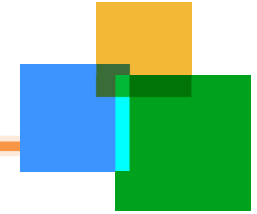
[North America, Europe, and Asia][OCO-2]

Hakkarainen et al., Direct space-based observations of anthropogenic CO₂ emission areas from OCO-2, *Geophysical Research Letters*, 2016

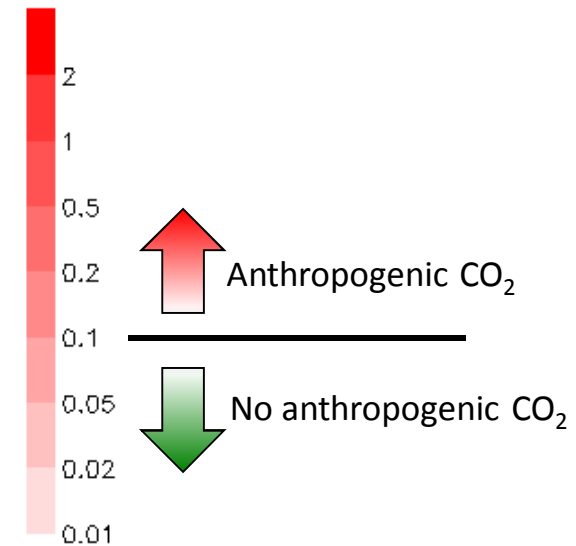
GOSAT Data Over Morocco



Anthropogenic CO₂ Concentration Based on Emission Inventories



[ppm]



Period : 3 days (Jan 9, 2010 2am -)

Time step : 2 hours

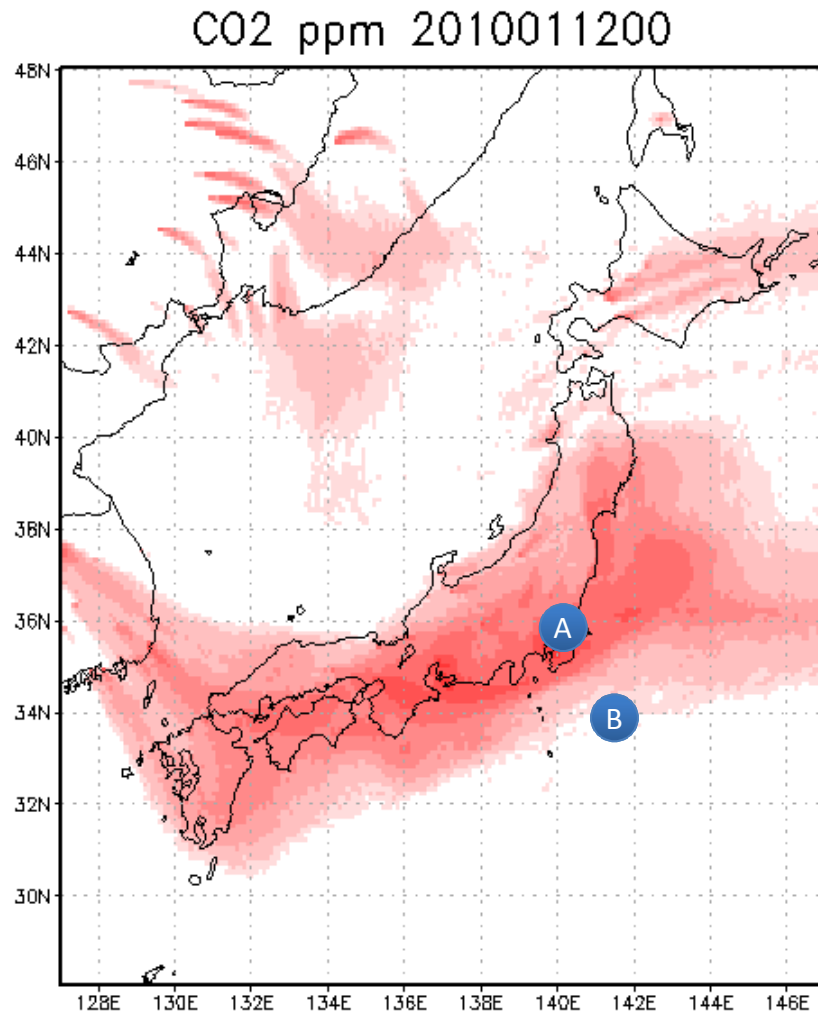
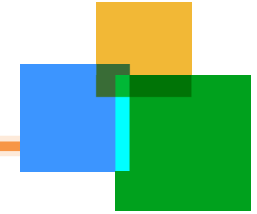
Grid size : 0.1 x 0.1 degree

Emission sources : >10 gC/m²/day

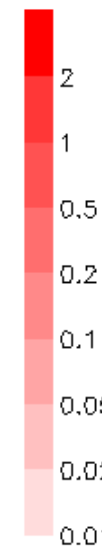
Concentration : Average CO₂ in Surface - 1km
(Based on ODIAC)

日々のGOSATデータの中から、人為起源CO₂の影響を強く受けたデータ(例:A)とあまり受けていないデータ(例:B)を同じ月の中で探し、その濃度の差(A-B)を「人為起源CO₂濃度」とする。

Anthropogenic CO₂ Concentration Based on Emission Inventories



[ppm]



人為起源CO₂の影響あり



人為起源CO₂の影響なし

計算期間: 3日間 (2010/1/9 午前2時~)
 計算間隔: 2時間
 グリッドサイズ: 0.1 x 0.1度
 排出源: 10 gC/m²/日以上
 結果: 地表~高度1kmまでの平均CO₂濃度
 (ODIACに基づく)

日々のGOSATデータの中から、人為起源CO₂の影響を強く受けたデータ(例:A)とあまり受けていないデータ(例:B)を同じ月の中で探し、その濃度の差(A-B)を「人為起源CO₂濃度」とする。