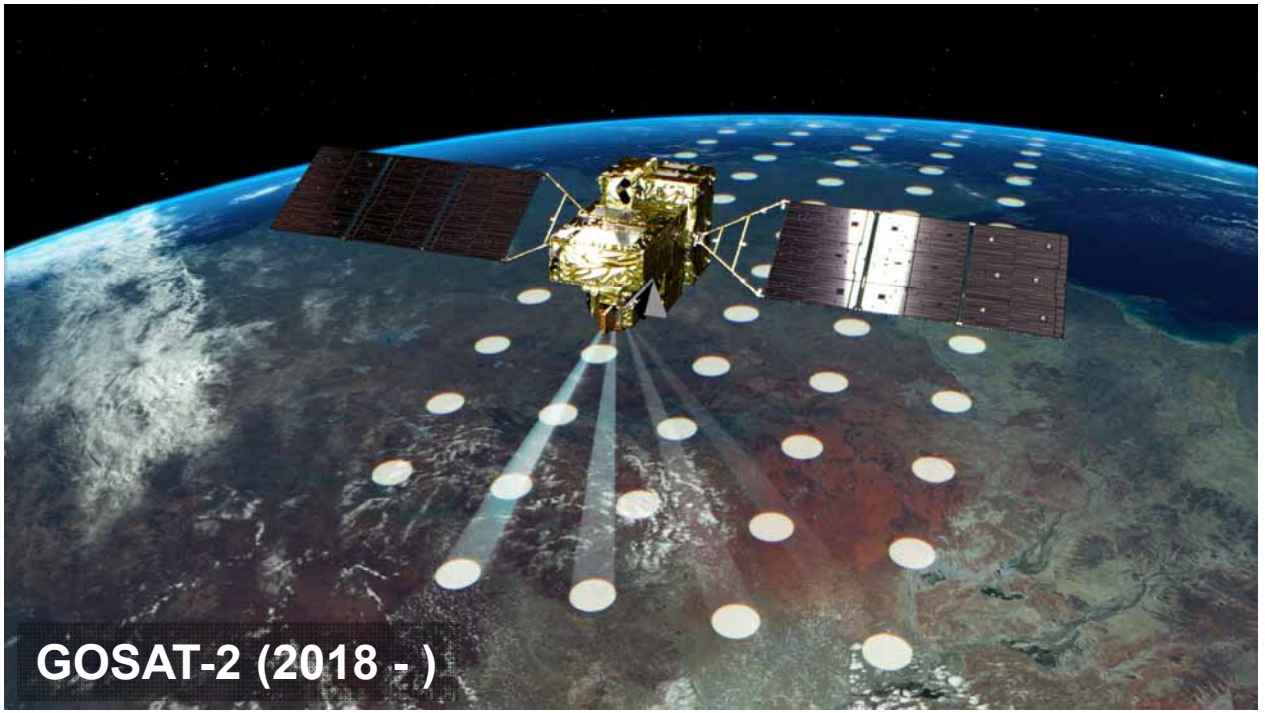
How to Use Satellite GHG Concentration Data for Verification of GHG Emissions Inventories



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Take-home Messages

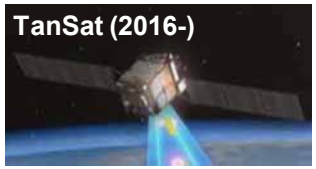
- ✓ We have satellite GHG data for more than 10 years. New satellites are going to be launched in coming years. **Data gaps will be avoided.**

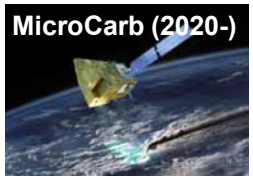
- ✓ Peer-reviewed papers regarding satellite – inventory comparison are being published. **Methodologies are not matured yet but promising.**

- ✓ It is high time to start discussion on how to use satellites to **verify GHG emission inventories.**

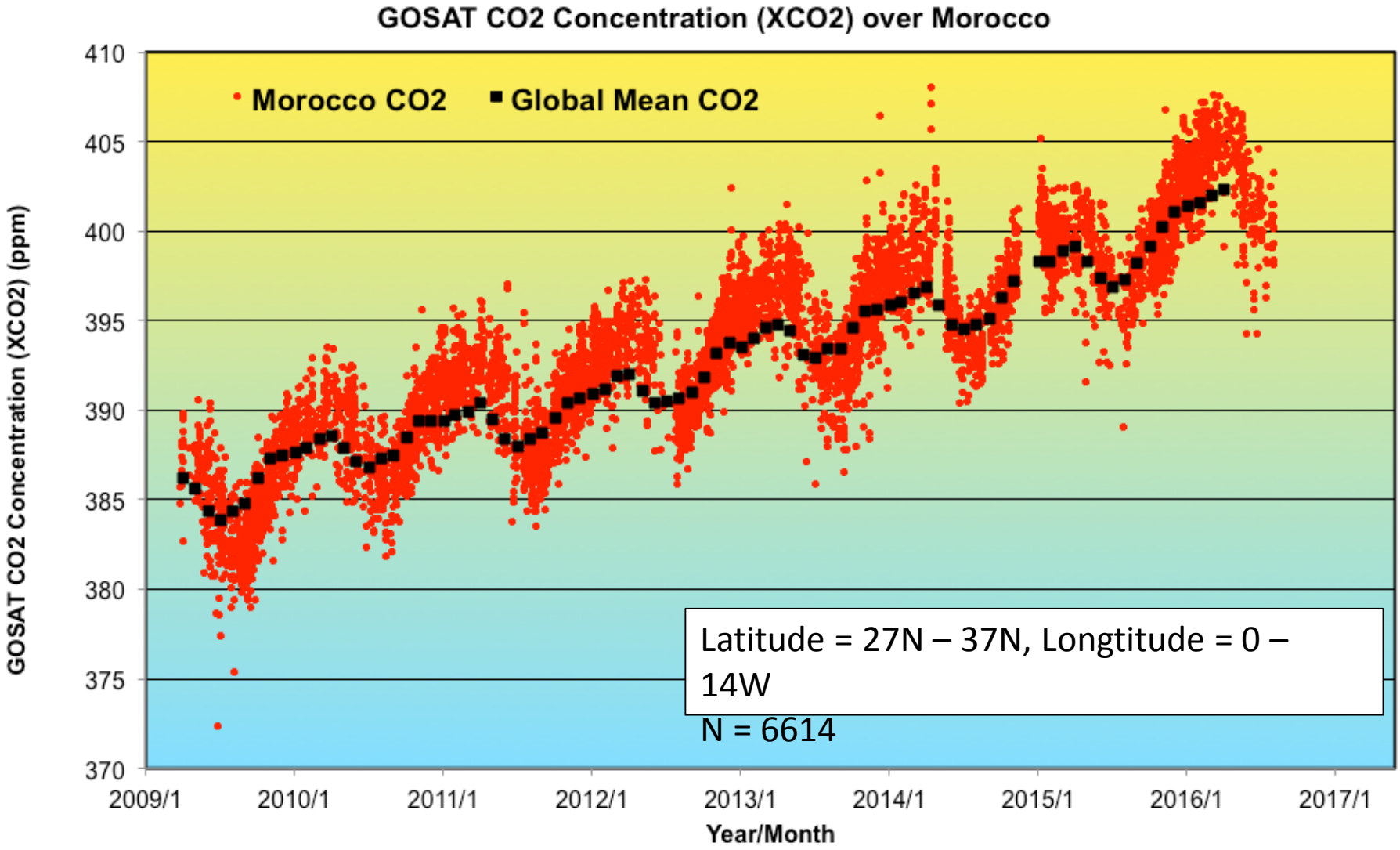
Satellites for Greenhouse Gases Observation

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	

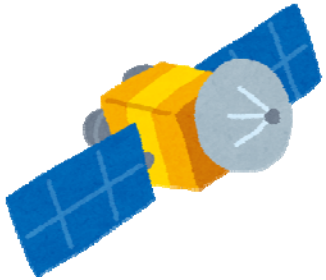


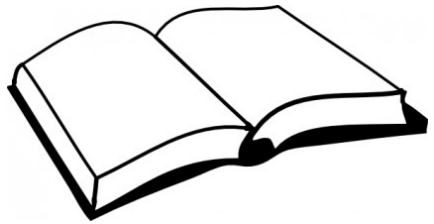


Morocco CO_2 Concentration by GOSAT



How to Compare Satellite and Inventory (1)





Satellite		**Inventory**
GHG atmospheric concentration Example : CO_2 = 400 ppm	⇔	GHG emission (flux) into atmosphere Example : CO_2 = 36 Gt CO_2 per year

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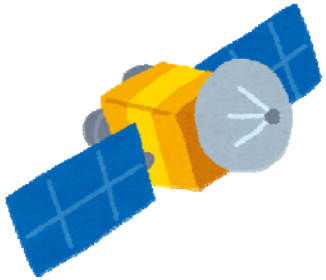
(Flux-based Method)

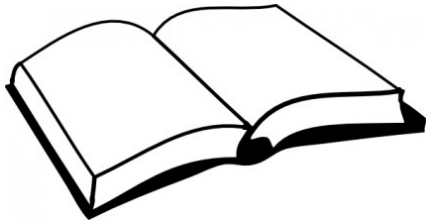
GHG Flux derived from satellite GHG concentration and atmospheric transport model	⇔	**Inventory** GHG emission (flux) into atmosphere

(Concentration-based Method)

Satellite GHG atmospheric concentration	⇔	GHG Concentration derived from inventory and atmospheric transport model

How to Compare Satellite and Inventory (2)

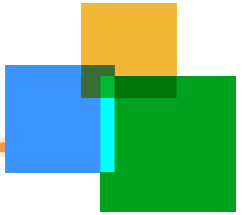




Satellite Sum of all sources and sinks	✕	**Inventory** Anthropogenic emission only

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



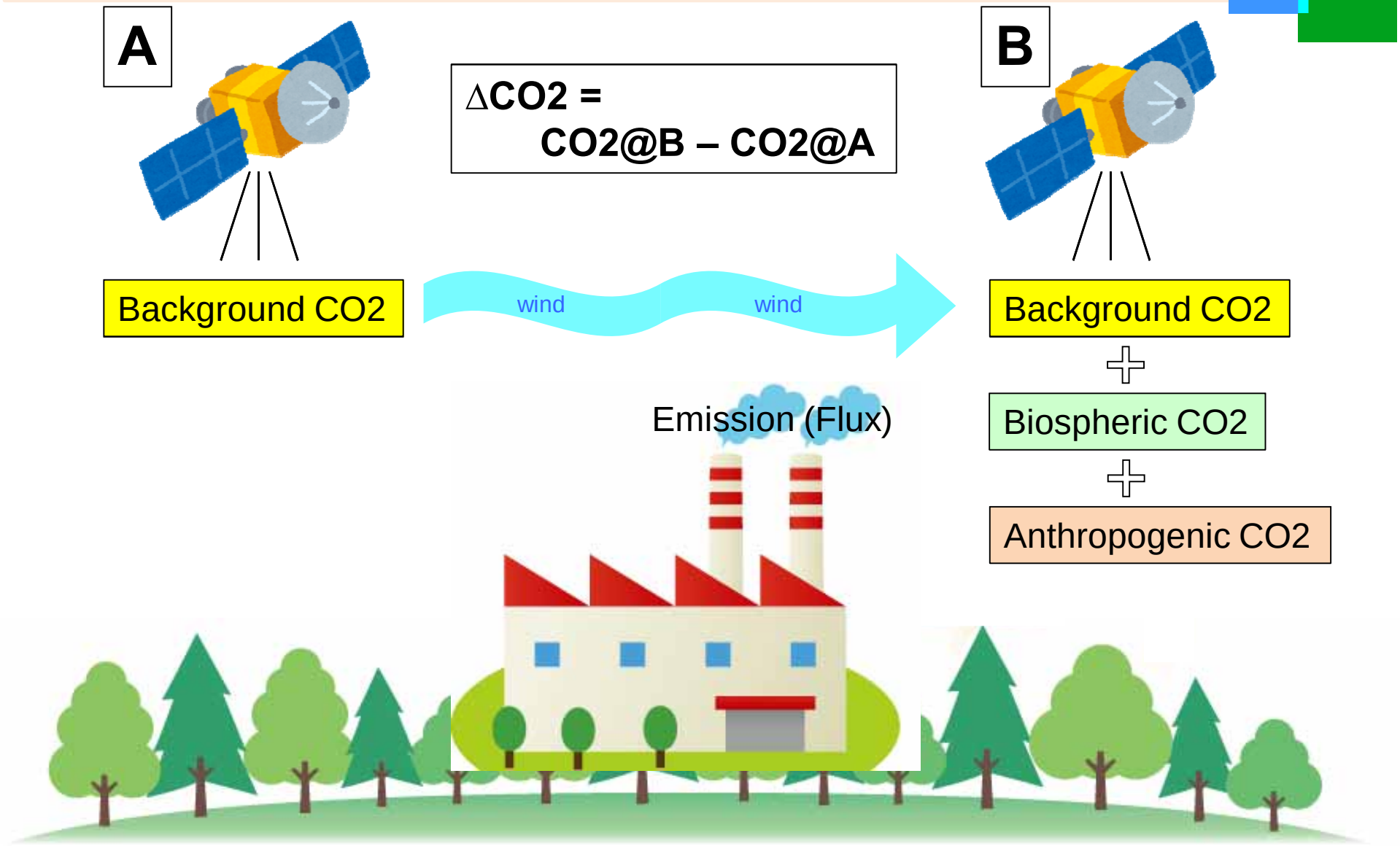
Flux-based Method

- 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.

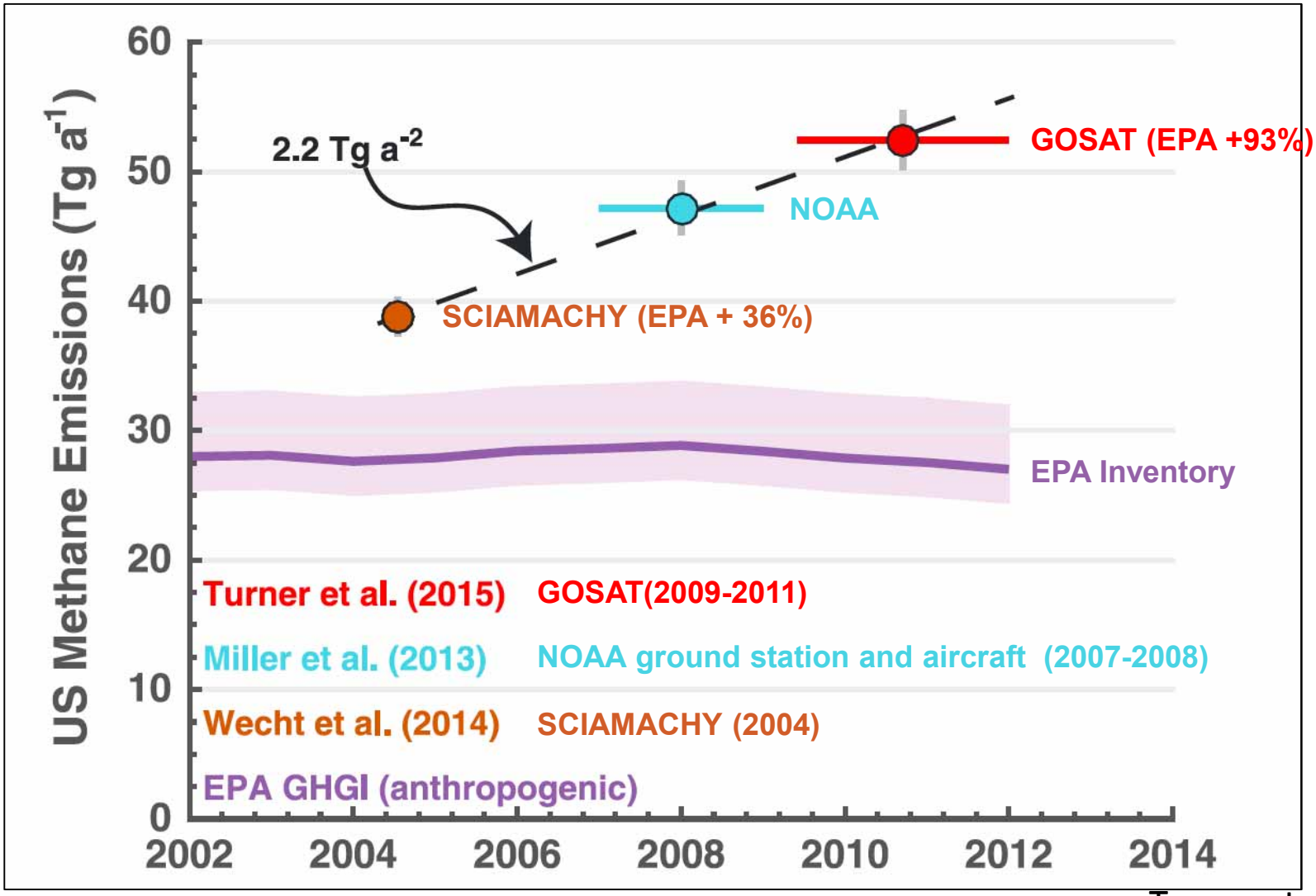
Concentration-based Method

- 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

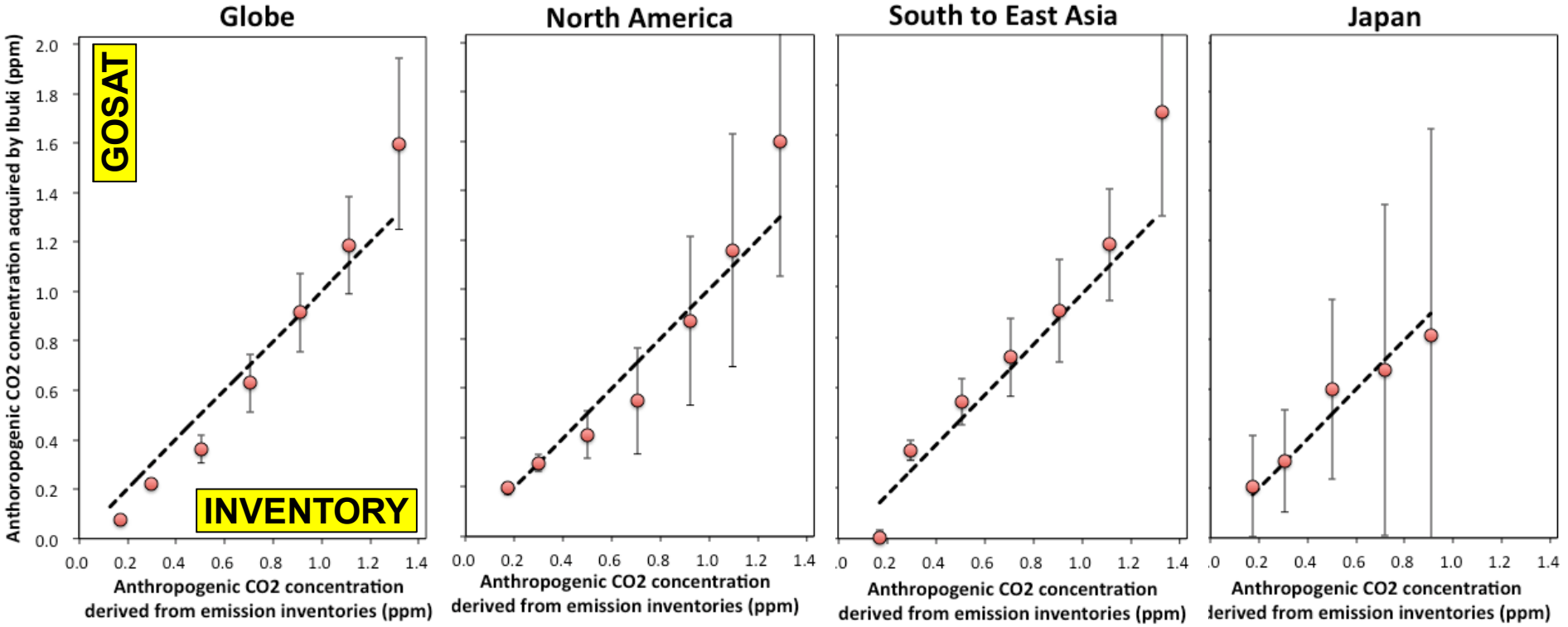


Flux-based method :
CONUS Methane Emission Comparison



Turner et al. (2016)

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



Globe	North America	South to East Asia	Japan
N = 13616	N = 4684	N = 5589	N = 396
Regression Slope	Regression Slope	Regression Slope	Regression Slope
1.08 ± 0.13	**0.99 ± 0.28**	**0.99 ± 0.17**	**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, *Atmosperic 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

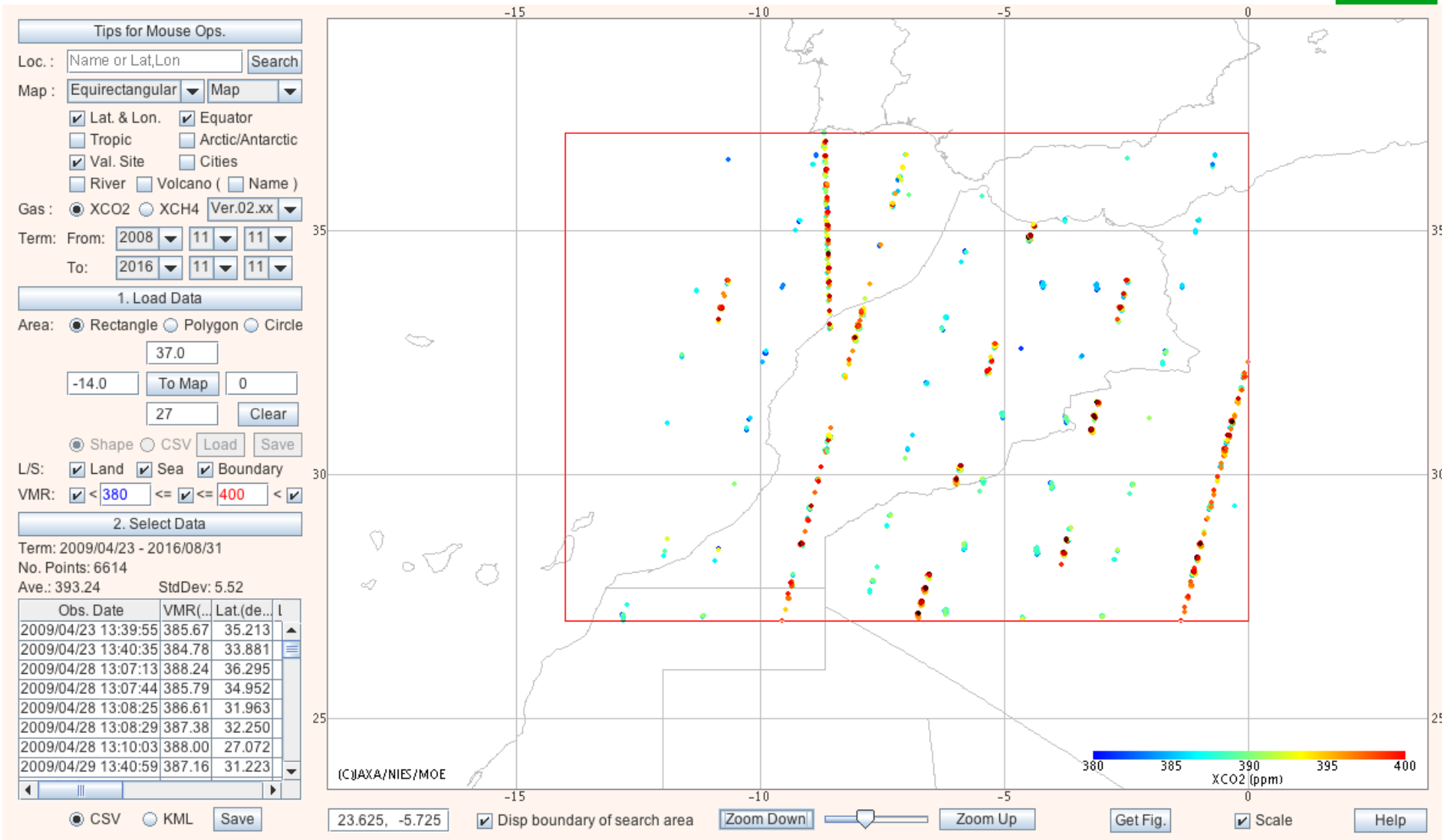
[Global, Asia, and North America][GOSAT]

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

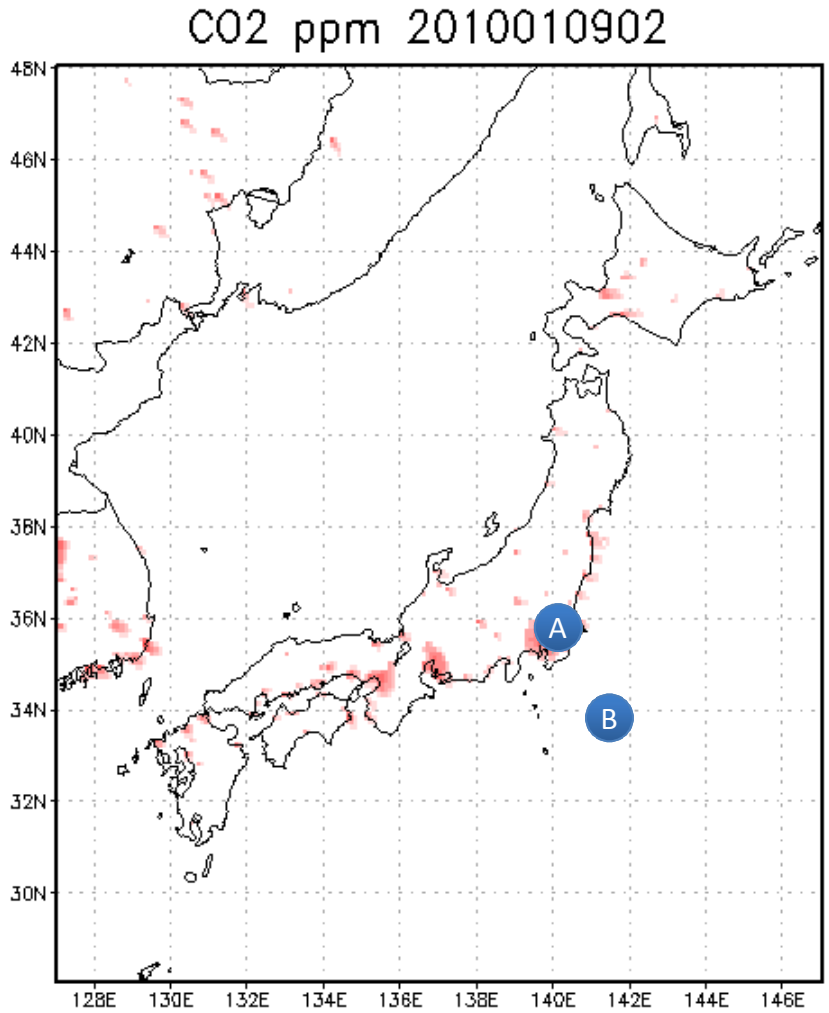
[North America, Europe, and Asia][OCO-2]

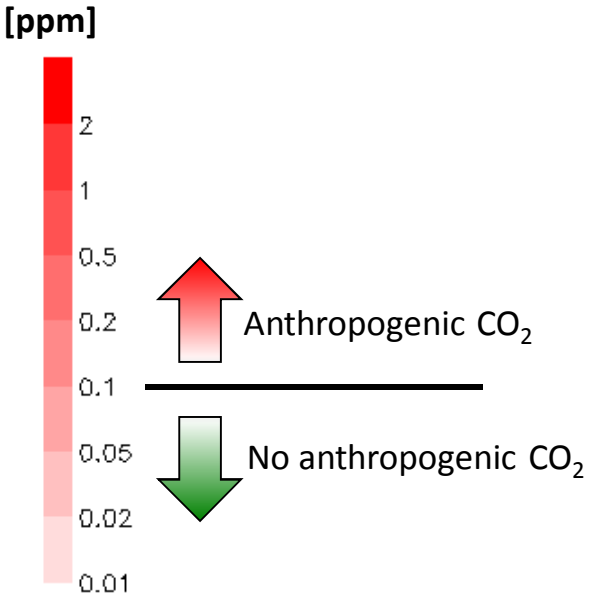
Hakkarainen et al., Direct space-based observations of anthropogenic CO2 emission areas fromOCO-2, *Geophysical Research Letters*, 2016

GOSAT Data Over Morocco



Anthoropogenic CO2 Concentration Based on Emission Inventories

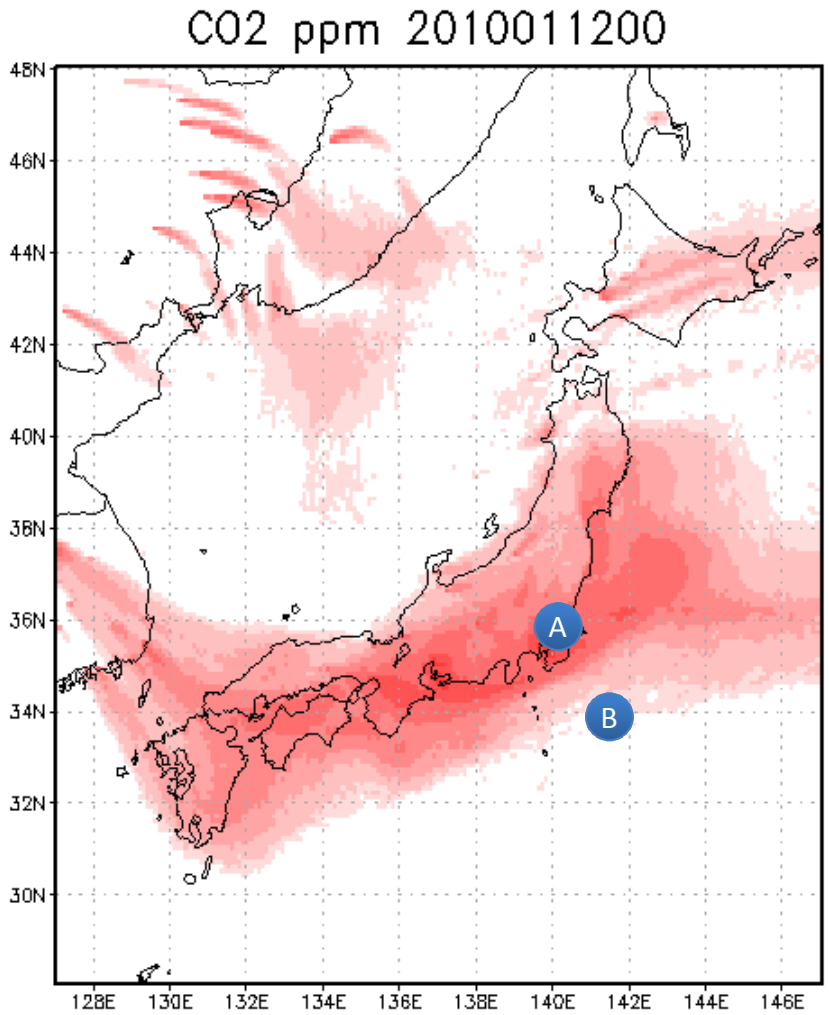




Period：3 days（Jan 9, 2010 2am -）
Time step： 2 hours
Grid size : 0.1 x 0.1 degree
Emission sources：>10 gC/m2/day
Concentration：Average CO2 in Surface – 1km
（Based on ODIAC）

日々のGOSATデータの中から、人為起源CO_2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CO_2濃度」とする。

Anthoropogenic CO2 Concentration Based on Emission Inventories



[ppm]

2
1
0.5
0.2
0.1
0.05
0.02
0.01

人為起源CO_2の影響あり

人為起源CO_2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CO_2濃度（ODIACに基づく）

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