IWGGMS-9
Yokohama
May. 29-31, 2013

Estimation of CO_2 emission strength from a mega-sized city using satellite and in situ observation data

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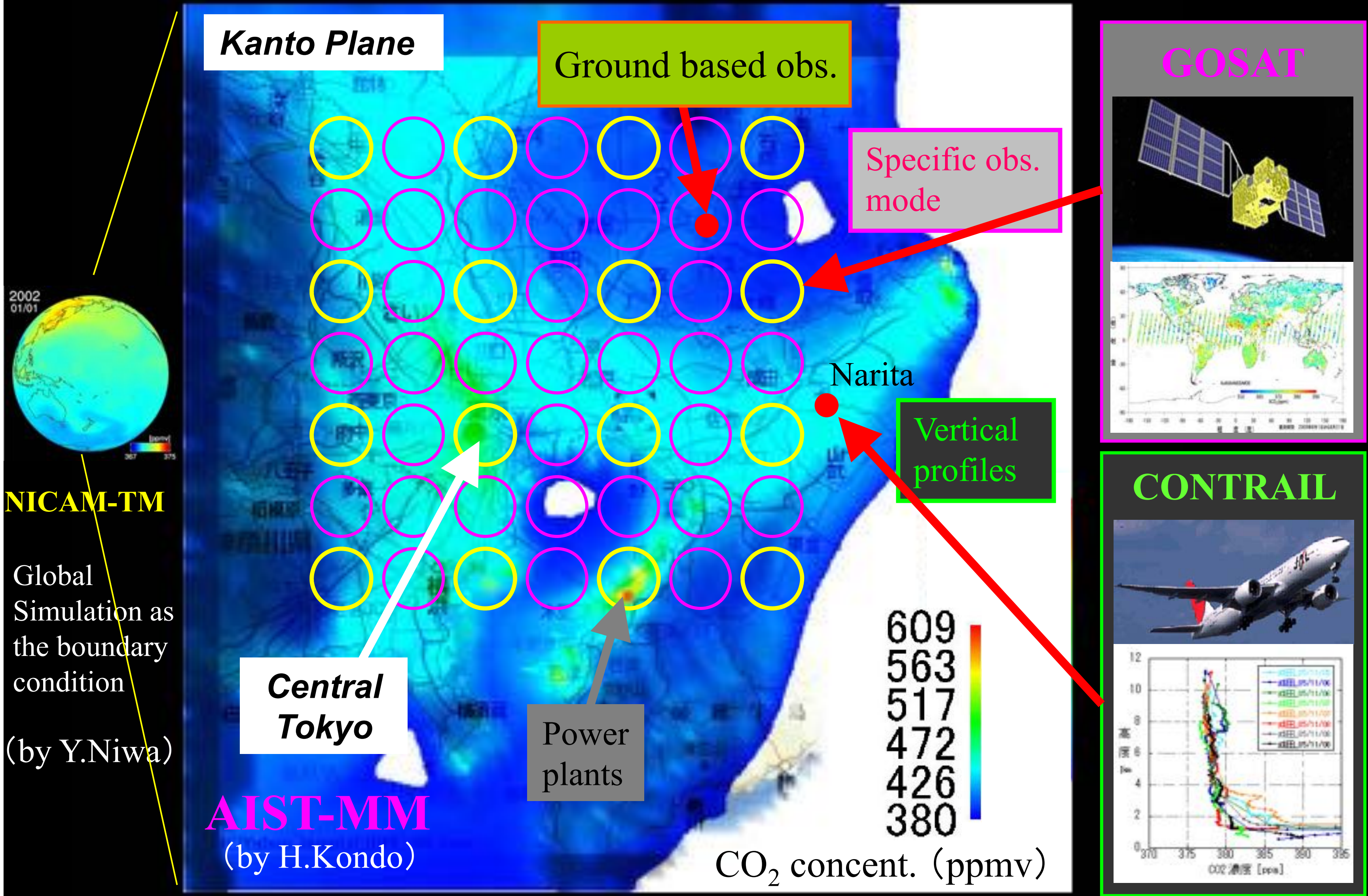
(4) National Institute for Environmental Studies (NIES)
(5) Solar-Terrestrial Environment Laboratory, Nagoya University
(6) Center for Environmental Remote Sensing (CEReS), Chiba University

CO_2 Data assimilation using AIST-MM and NICAM-TM



Objective : Developing CO_2 Data assimilation system for assessing urban CO_2 emissions

Observational data

【Monitoring by local government】《ground based, continuous: hourly》

Center for Environmental Science in Saitama (WDCGG) ： 2000～

Tokyo Metropolitan Res. Inst. for Environmental Protection ・・・ 2000～

Ibaraki prefectural government ・・・ 2000(2004)～

Kanagawa prefecture, Chiba prefecture ・・・?

【CONTRAIL】《Vertical profiles, upper tropospheric concentration》

Data provided by Dr. Machida (NIES), Dr. Matsueda and Sawa (MRI/JMA)

※Vertical profiles around Narita airport (Chiba pref.)

(Machida et al., doi:10.1175/2008JTECHA1082.1, 2008)

【GOSAT】《SWIR:XCO_2, TIR: upper tropospheric concentrations》

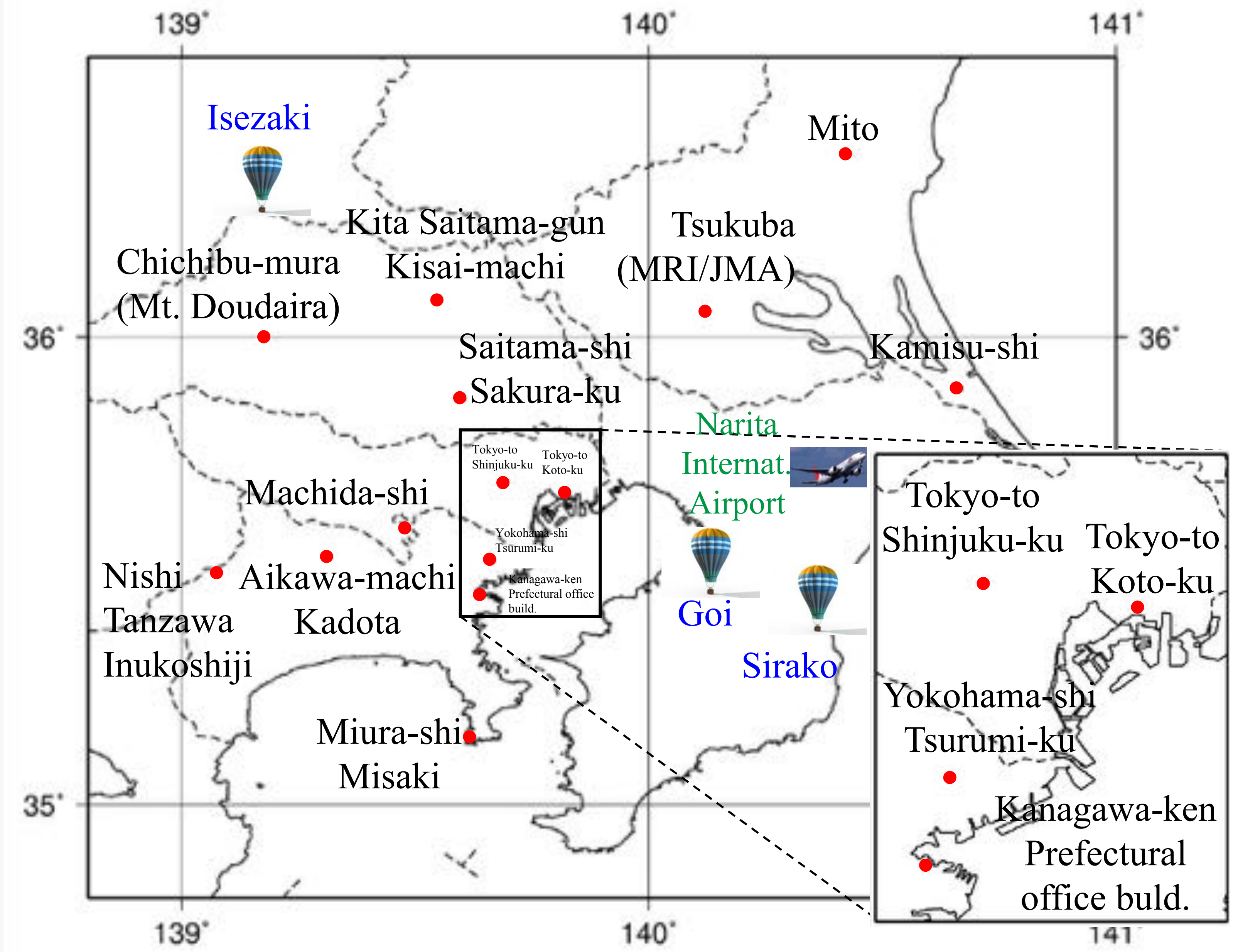
Targeting mode observations conducted GOSAT science team

1 path/6days, simultaneous16(14) points over the Kanto plain

2 modes (validation point mode, mesh mode)

2010.11～present

Location of ground observation sites (ground, sonde, airplane)



Transport model (forward calculation, inverse analysis)

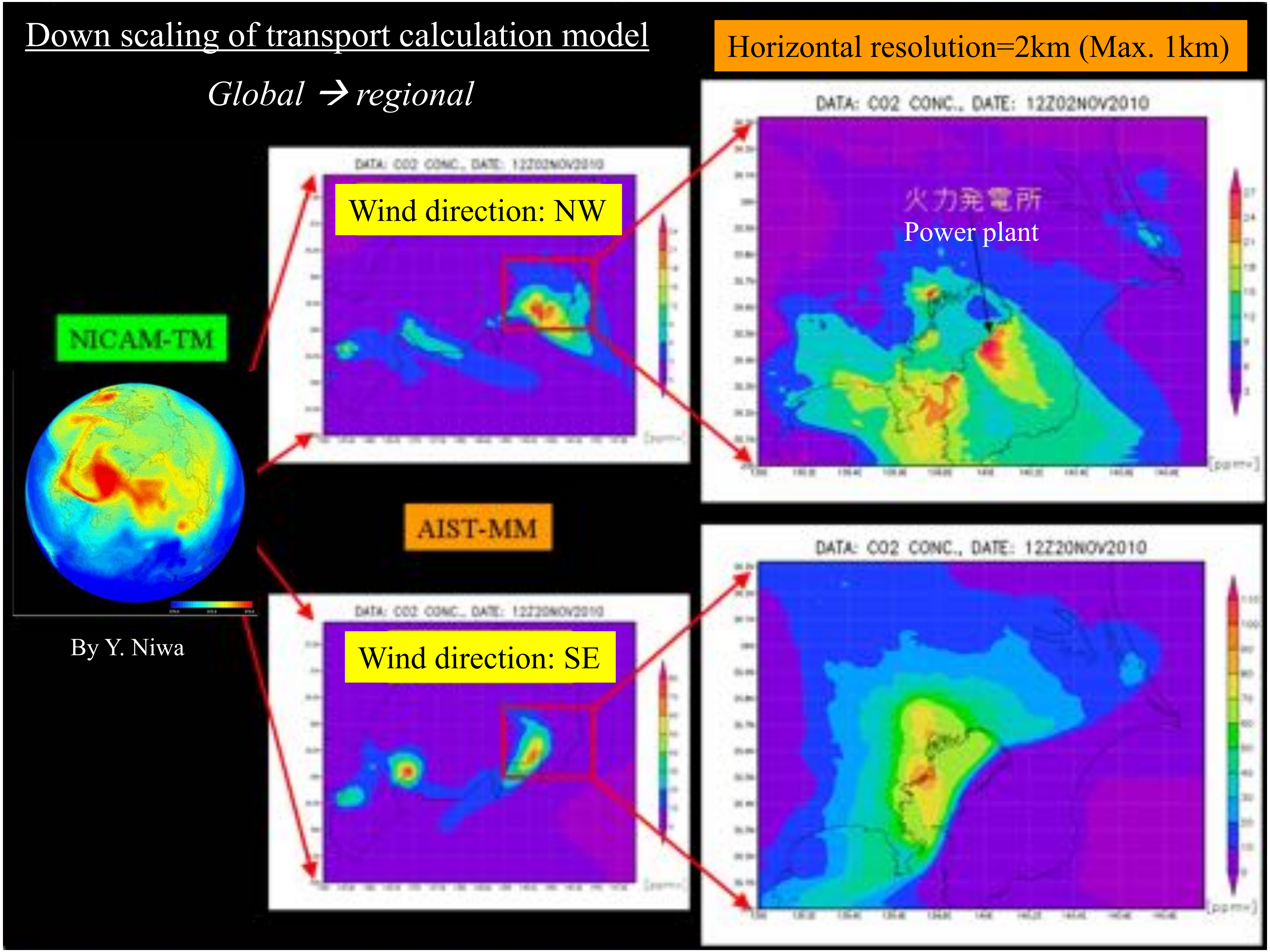
【NICAM-TM】《Global scale model based on GCM》

- Originally developed by Dr. Niwa (AORI/Univ. Tokyo, present affil. MRI/JMA)
  (Niwa, Y., et al., J. Meteo. Soc. Jpn., 89, 255-, 2011)
- Nudging of meteorological data： NCEP
- Fossil fuel emission, Surface flux based on a biosphere mode (CASA)
  Biomass burning（GFED3）,
  Ocean uptake (Takahashi, 2008)

【AIST-MM】《Regional scale model》

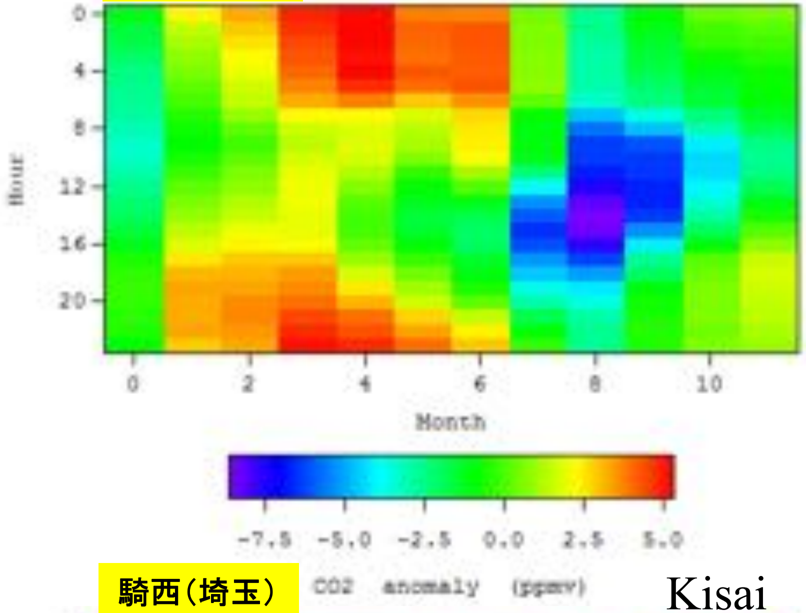
- Originally developed by Dr. Kondo (AIST)
  (Kondo, H., J. Meteo. Soc. Jpn. 68, 419–, 1990,
  Kannari, A. et al., *Atmos. Env.*, 41, 3428-, 2007)
- Nudging of meteorological data： GPV-MSM（forcast）
- Anthropogenic emissions（Kannari, 2000）, uptake by biosphere

※Inversion analysis： Synthesis inversion

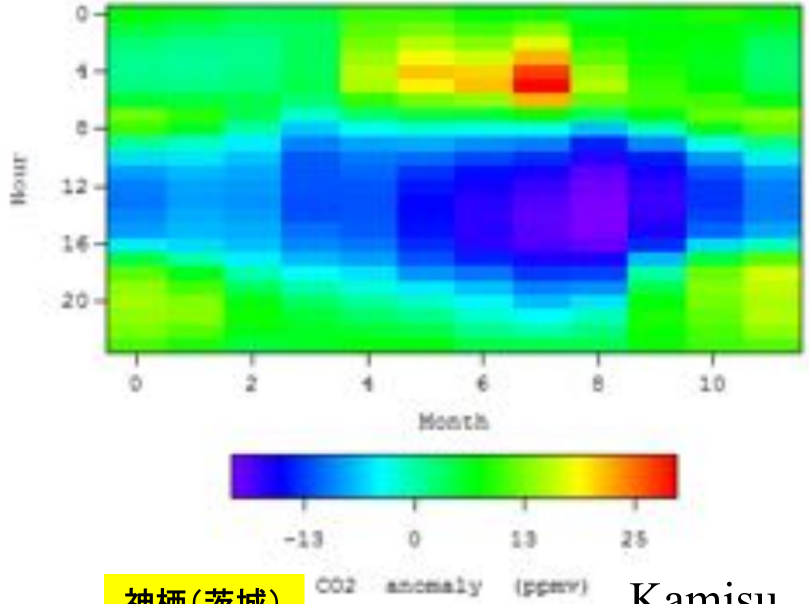

Down scaling of transport calculation model
Global → regional
Horizontal resolution=2km (Max. 1km)
NICAM-TM
By Y. Niwa
AIST-MM
DATA: CO2 CONC., DATE: 12Z02NOV2010
Wind direction: NW
DATA: CO2 CONC., DATE: 12Z20NOV2010
Wind direction: SE
火力発電所
Power plant

Seasonal variation of CO_2 diurnal cycle at the surface

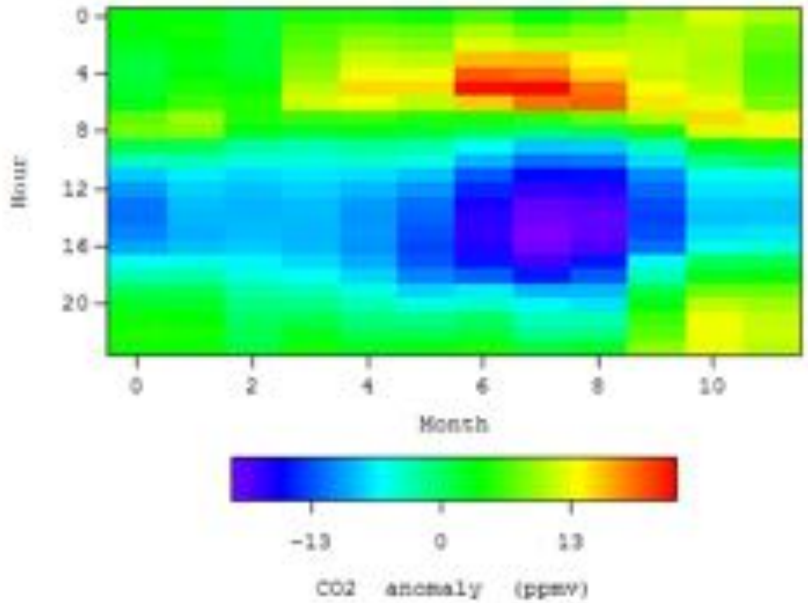
堂平(埼玉) Dodaira



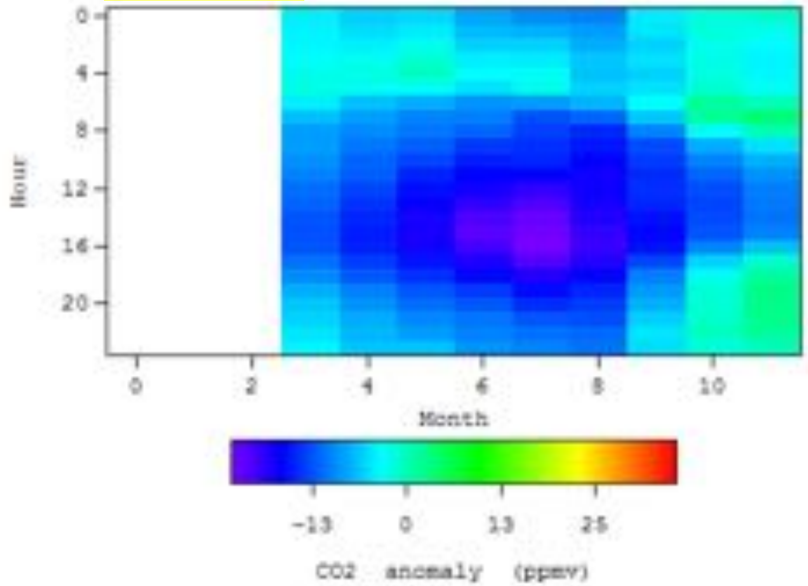
水戸(茨城) Mito



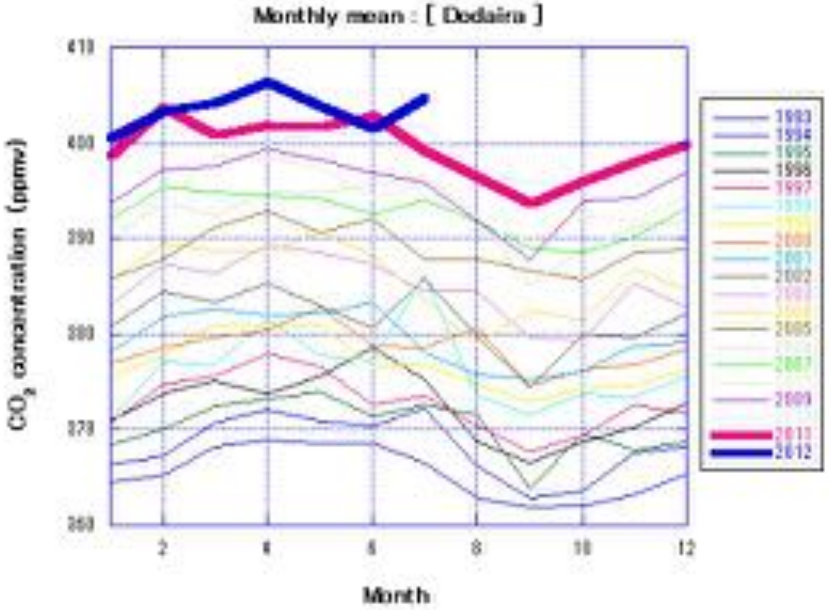
騎西(埼玉) Kisai

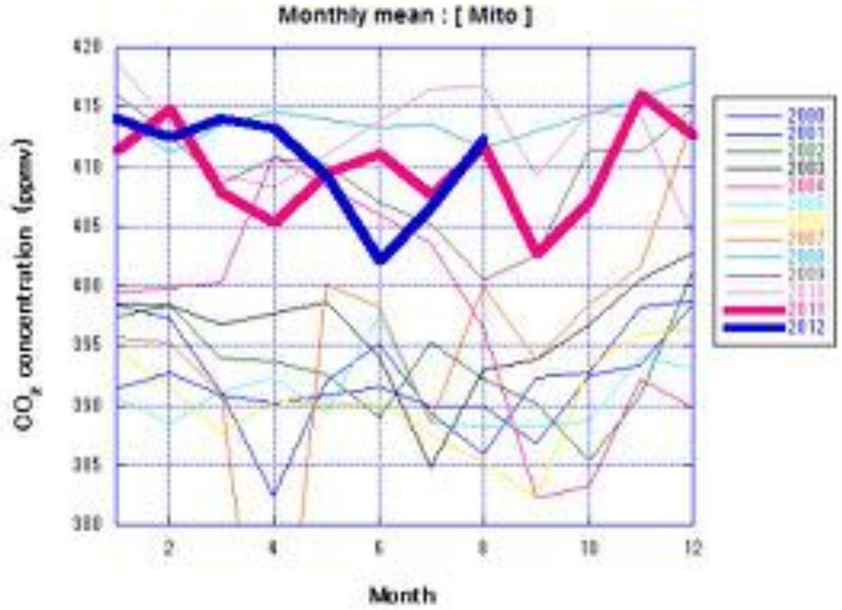


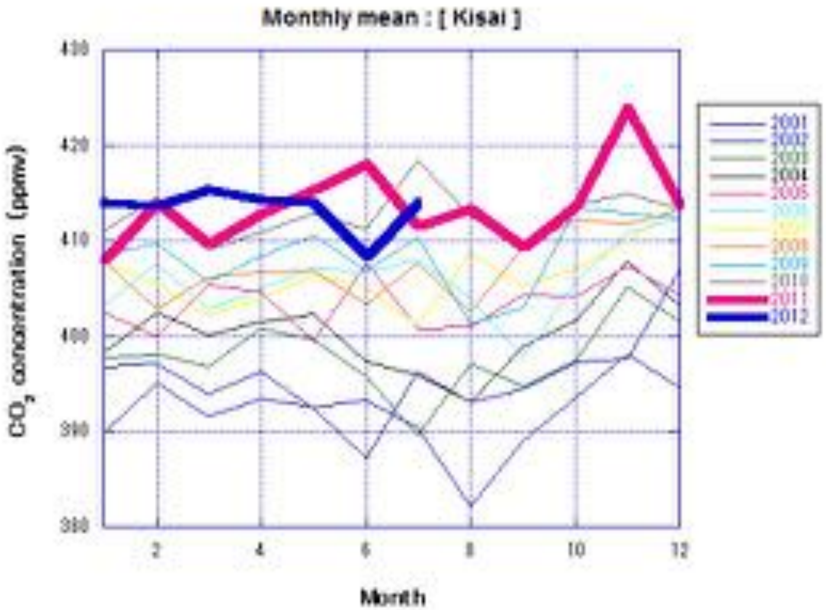
神栖(茨城) Kamisu

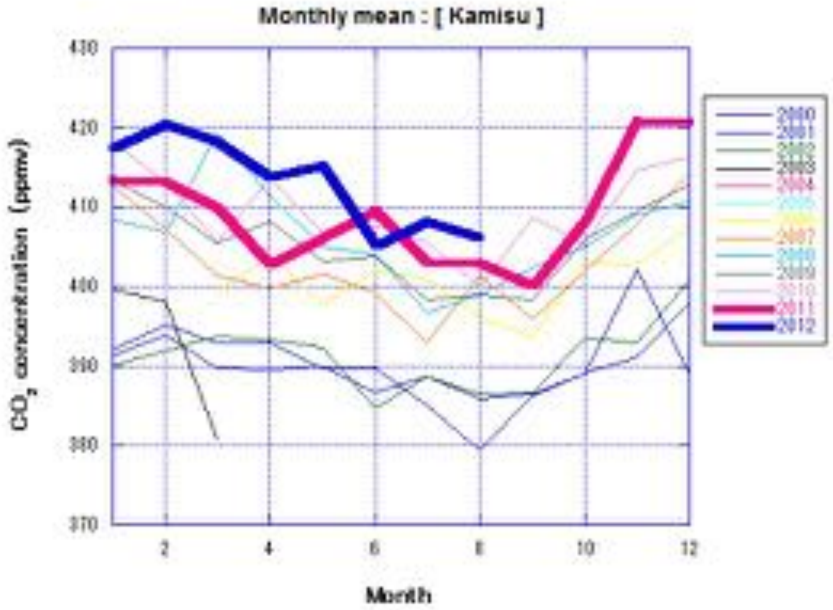


Changes in CO_2 concentrations detected after the Tohoku-Pacific Ocean Earthquake



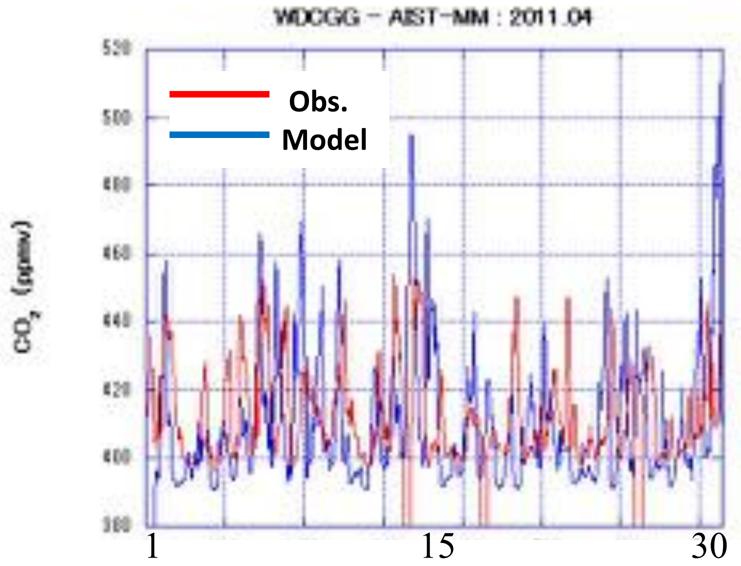


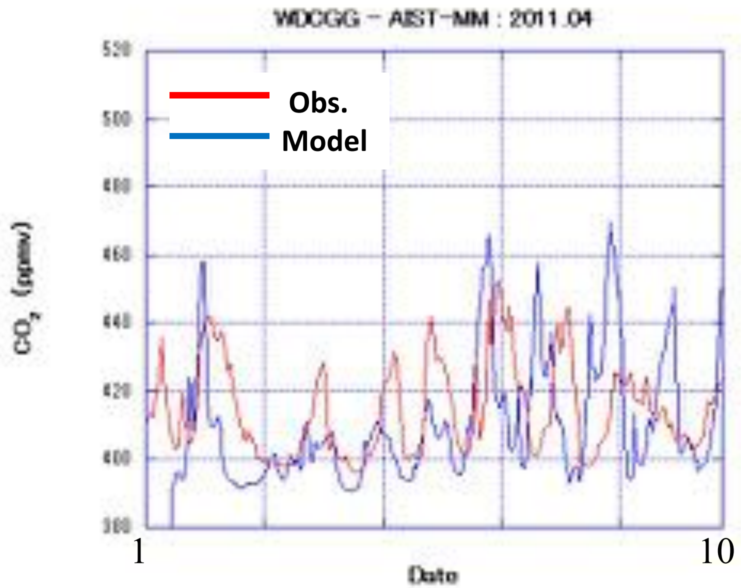




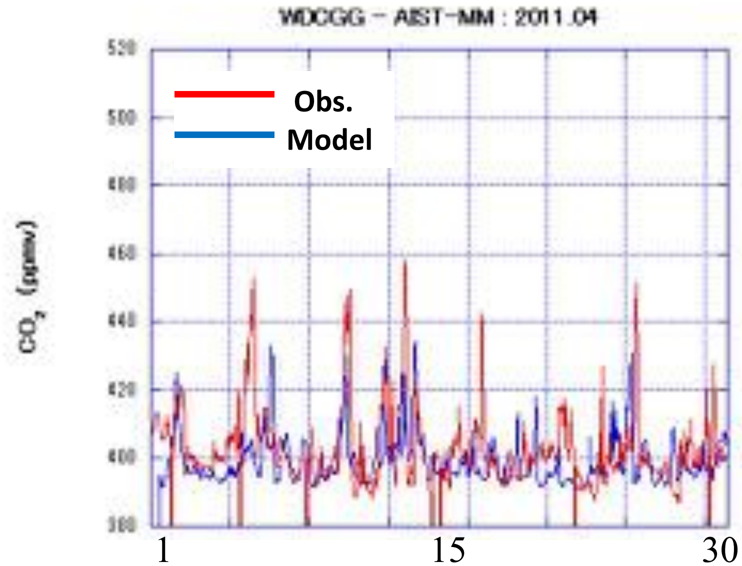
Comparison between observation and model calculation

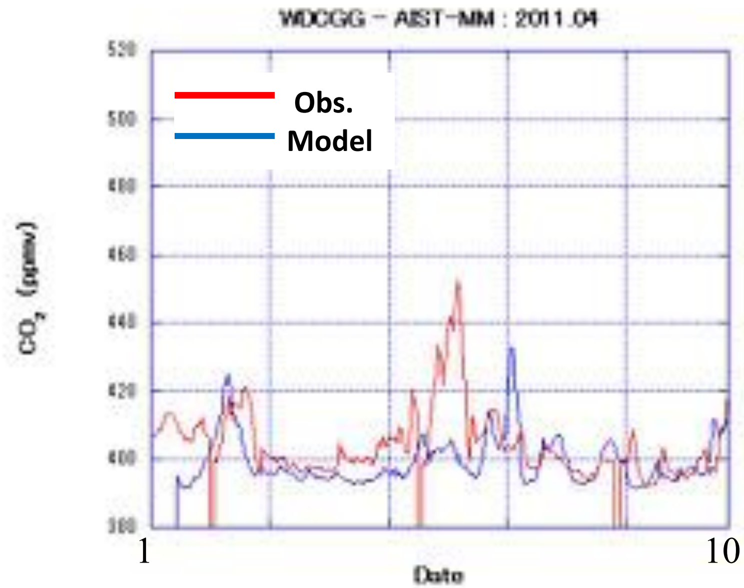
Kisai（Saitama）





Kamis（Ibaraki）





CO2: GOSATによる関東集中観測開始

注)衛星運用は JAXA, NIES が実施
本研究課題では観測要求とデータ解析を実施

- CO2、O3、CH4観測点の強化とデータ蓄積
- GOSATのメインセンサー“**TANSO-FTS**”の特定点観測モード利用
- 4点×4 点(計16点)の集中観測を2010年11月を開始
- すべての検証点を含むタイプ1と、関東地域をほぼ等間隔でカバーするタイプ2を設定し、それぞれ12日おき、2つのモードを併せて、6日ごとに集中観測を実施

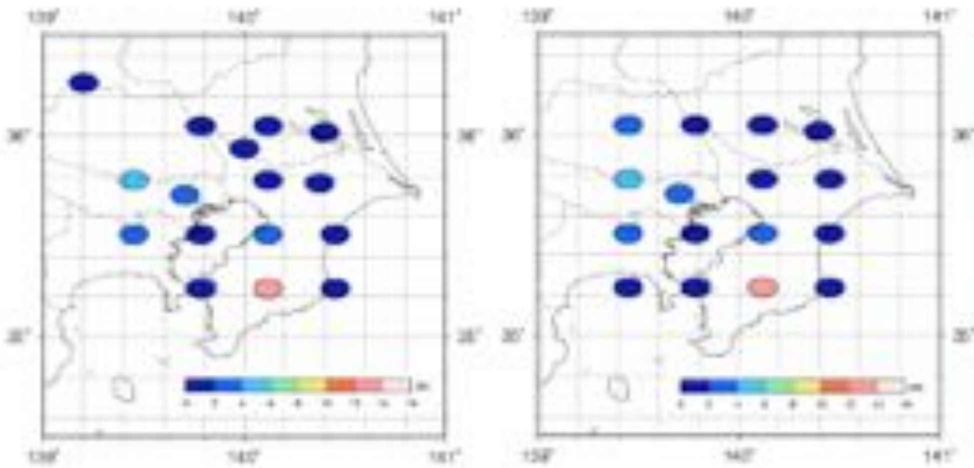


図1 GOSAT集中観測における2つの観測パターンにおける観測地点。左がタイプ1で全検証点を含む。右がタイプ2でほぼメッシュ点における観測。色は視野内の標高の分散値。

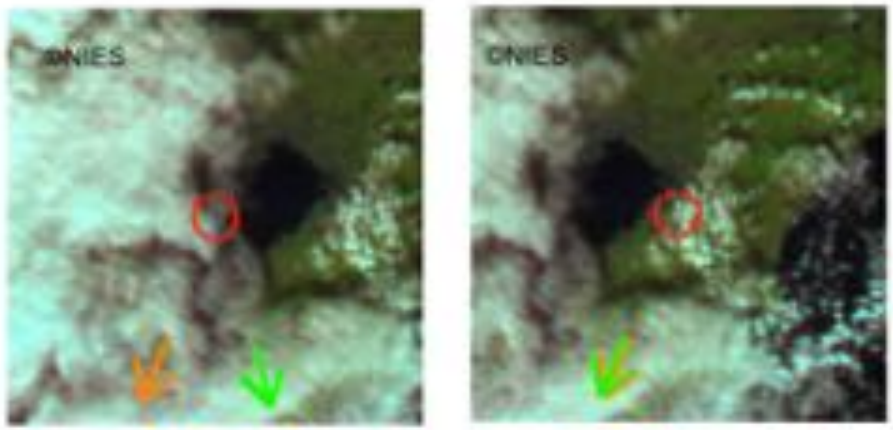


図2 GOSAT集中観測時のTANSO-CAI 画像の例。観測日は2010年12月2日。この日はあいにく曇り点が多かった。（データ: 国立環境研究所提供）

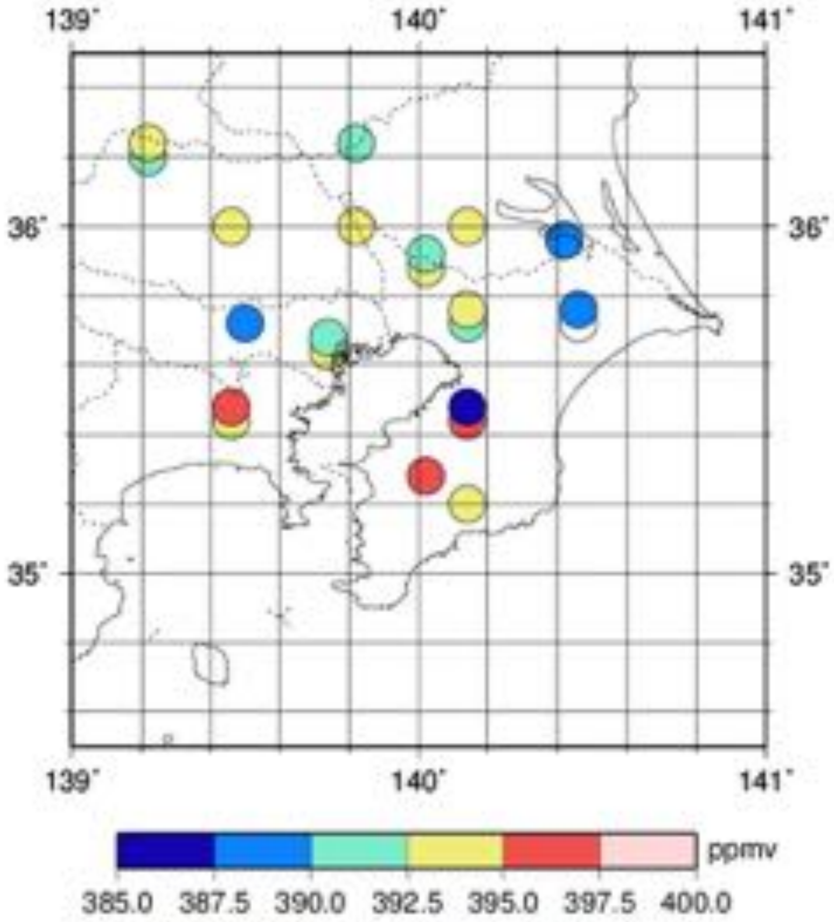
	Obs. pint No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
type2	2010/11/02	／	／	×	○	×	○	○	○	×	×	×	×	×	×	×	×
	2010/11/14	／	／	×	×	×	×	×	×	×	×	×	×	×	×	×	×
	2010/11/26	／	／	×	×	×	×	×	×	×	×	×	×	×	×	×	×
type1	2010/11/08	／	×	○	◎	○	○	○	○	○	×	×	×	◎	◎	×	×
	2010/11/20	／	×	×	×	×	×	×	×	×	○	×	○	×	○	×	×

2010年11月の観測結果のまとめ。“斜線”, “×”, “○”, “◎” はそれぞれ、“欠測”, “曇天”, “晴天、ただしL2データ未処理”, “L2データまで処理完了”である。

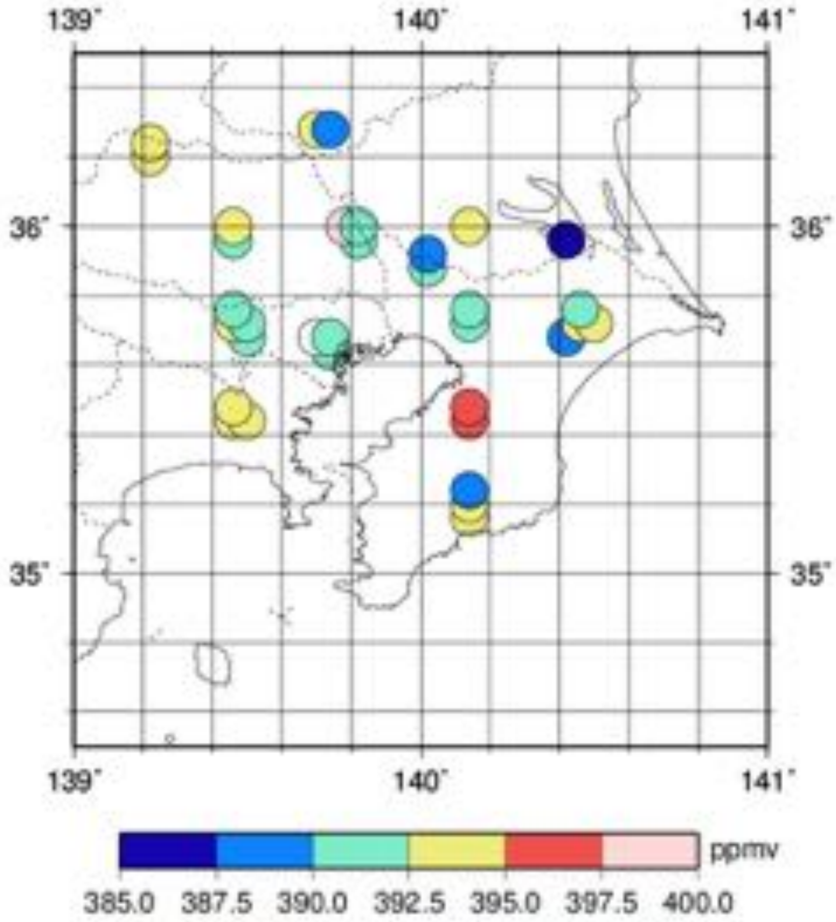
XCO_2 observed by GOSAT TANSO-FTS (SWIR) over the Kanto Plain

2010.11 ～ 2012.11

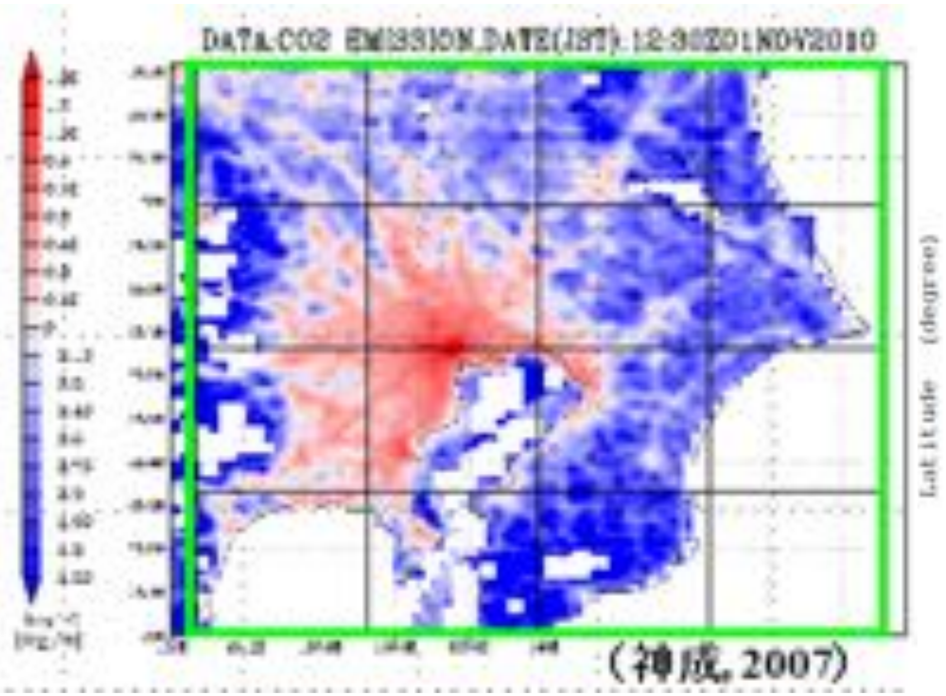
May～September



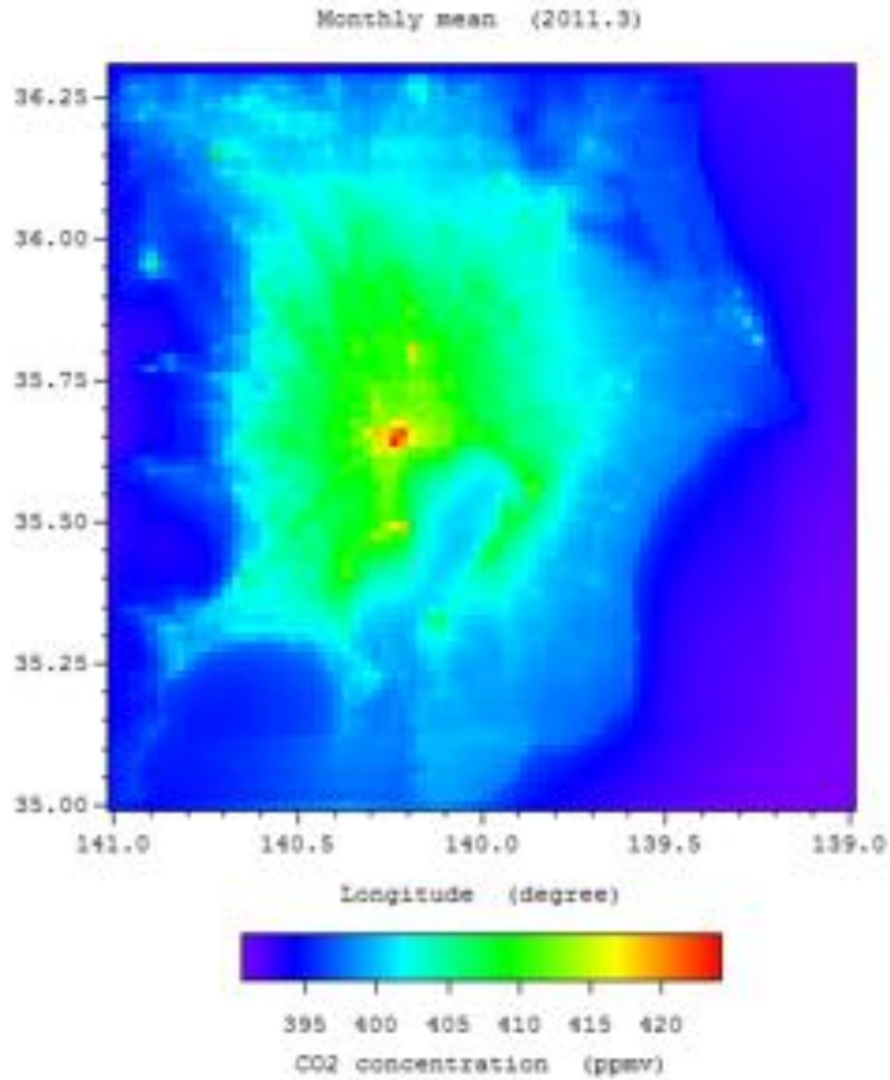
October～April



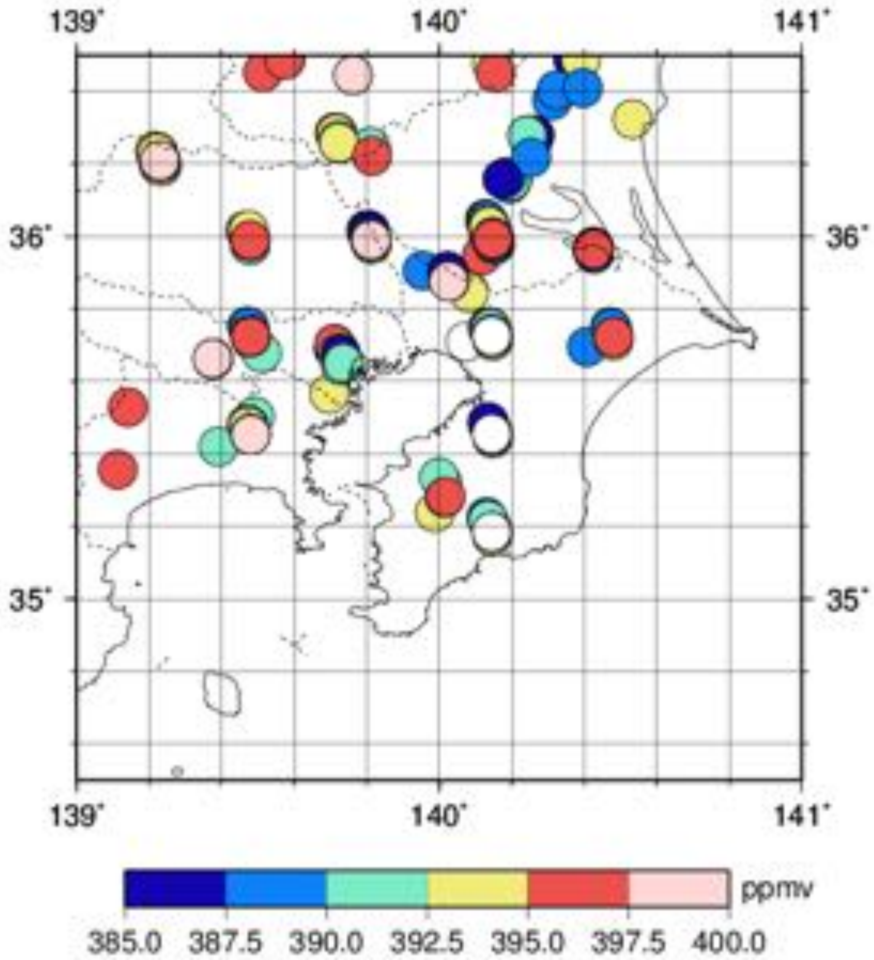
CO_2 Emission inventory data



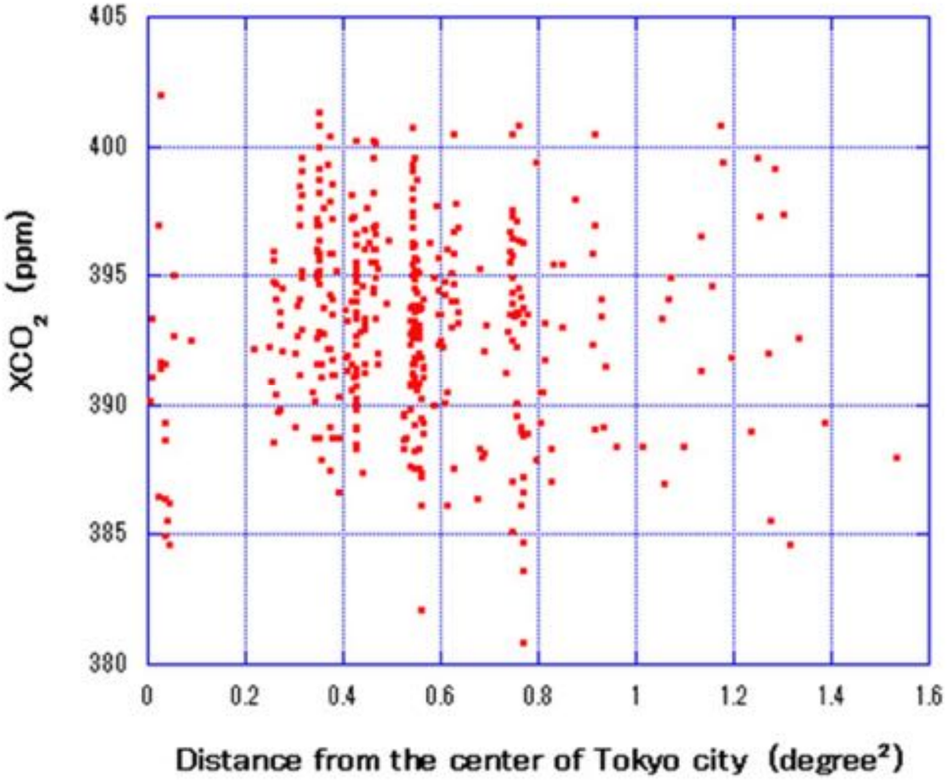
Mothly mean CO_2 surface concentration calculated by AIST-MM for 2011.3



GOSAT-SWIR - XCO_2
2010.11～2013.3

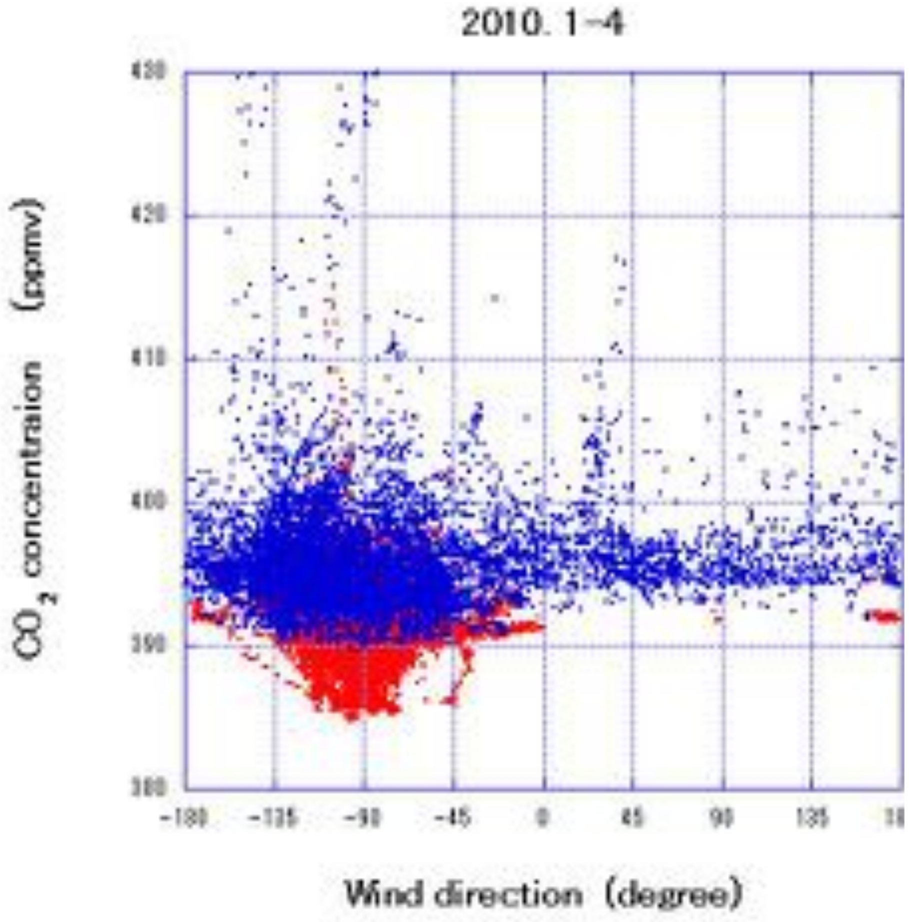


GOSAT-SWIR-XCO_2 as a function of distance of obs. point from the center of the Tokyo city



Relationship between XCO_2 and wind direction/speed

CONTRAIL 2009

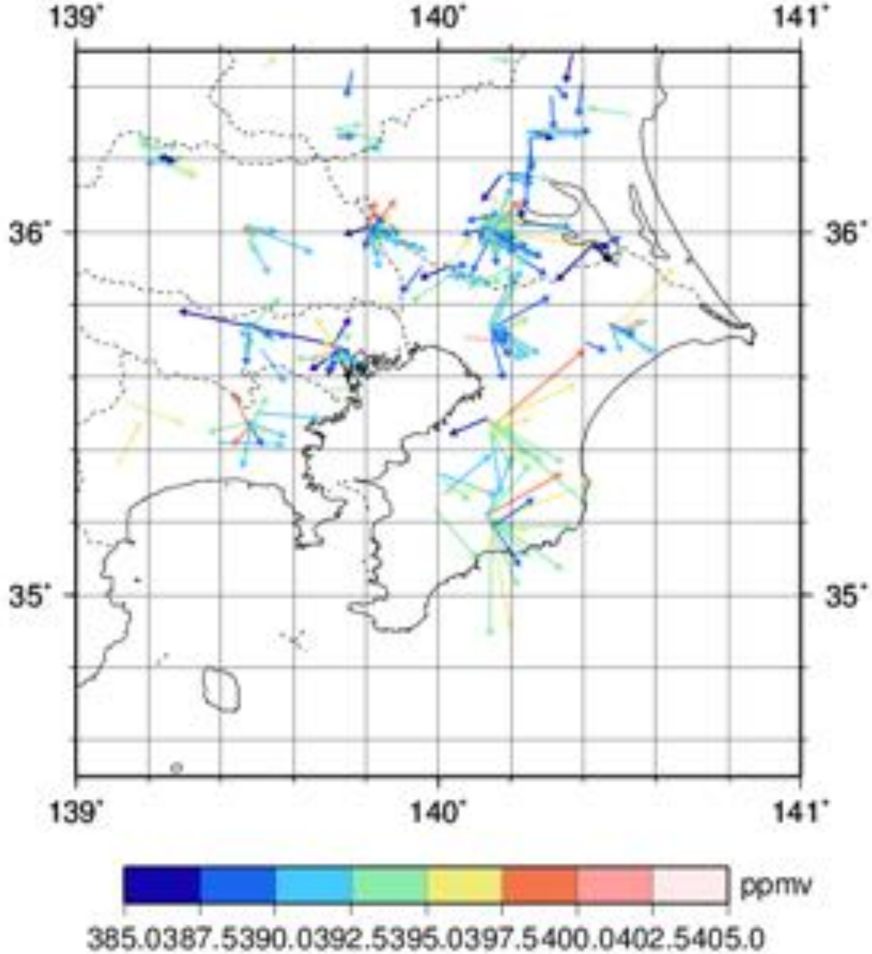


● : all
● : < 3 km

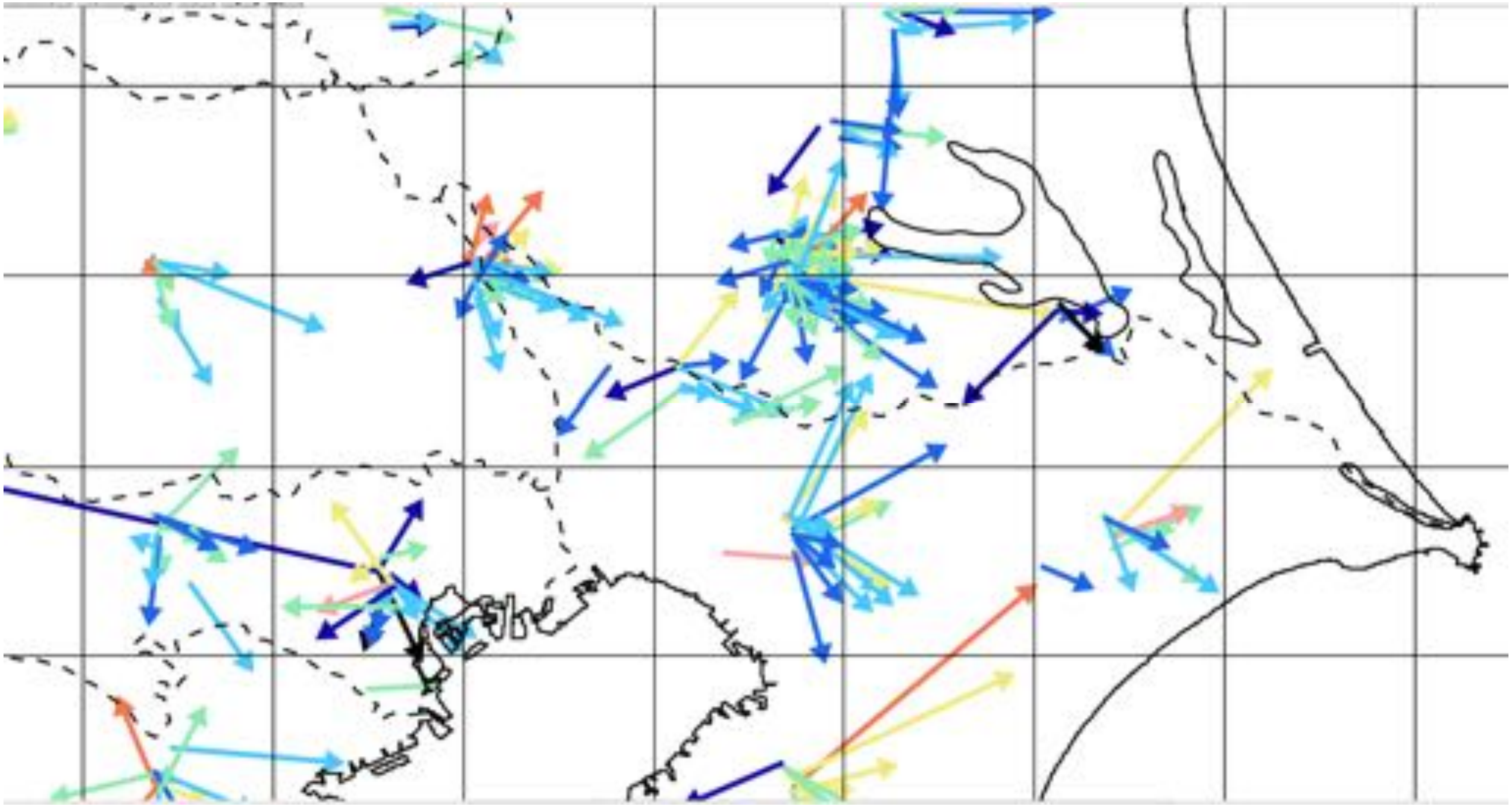
(Data : T. Machida)

GOSAT-XCO_2 vs Wind direct./speed

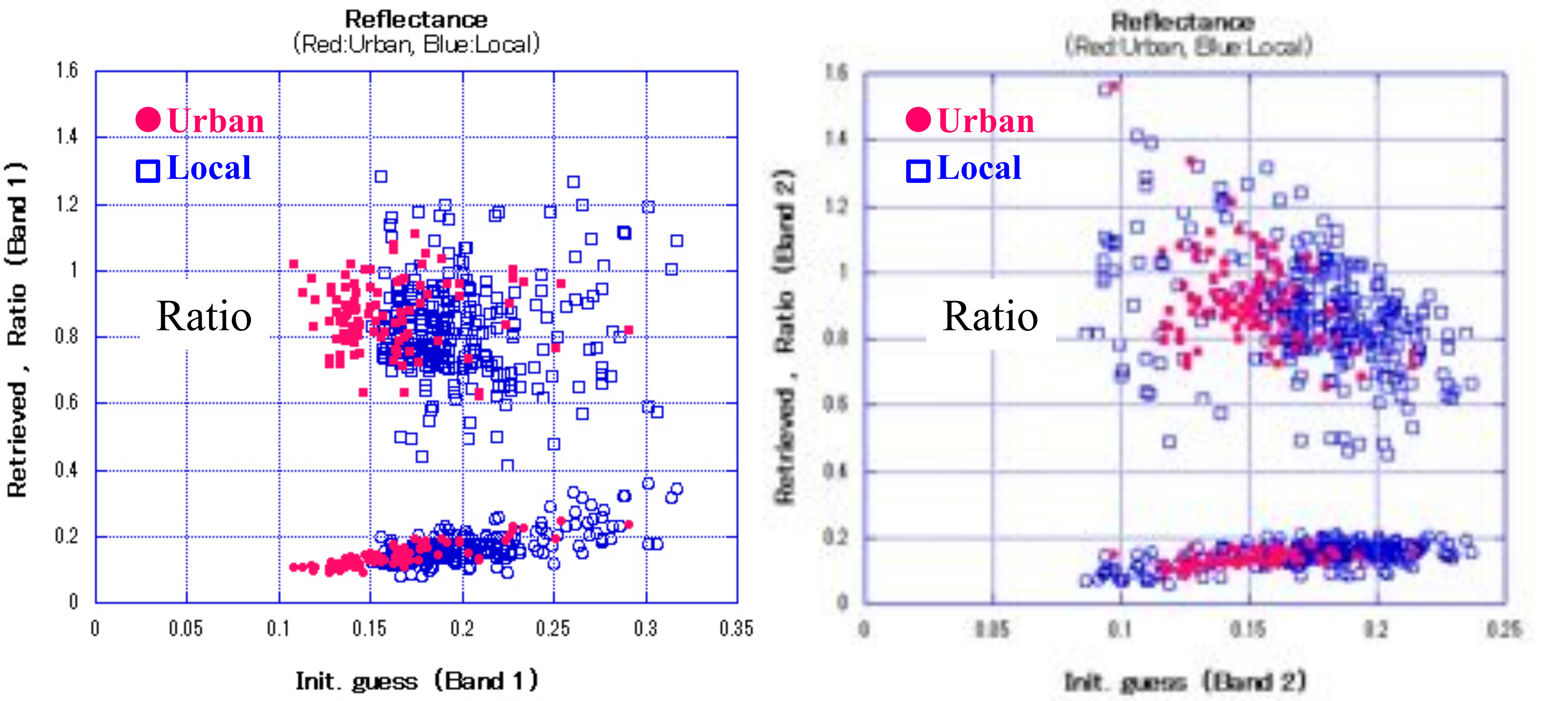
2010.11～2013.3.



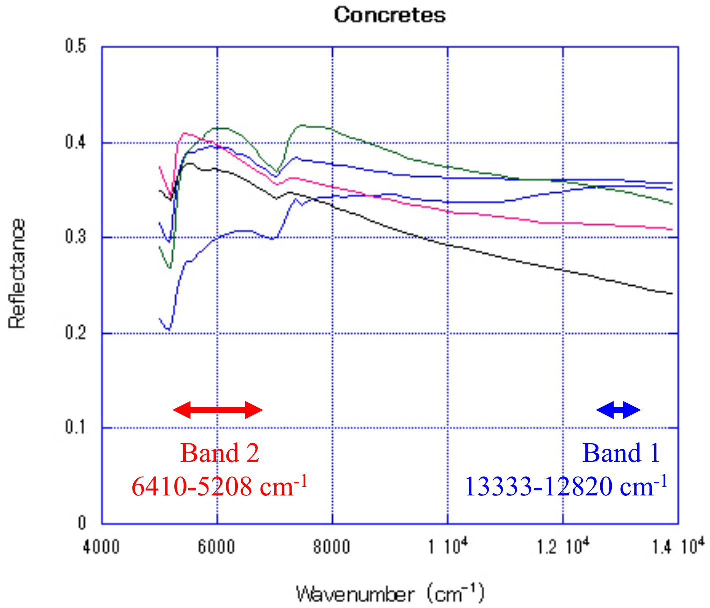
Relationship between XCO_2 and wind direction/speed

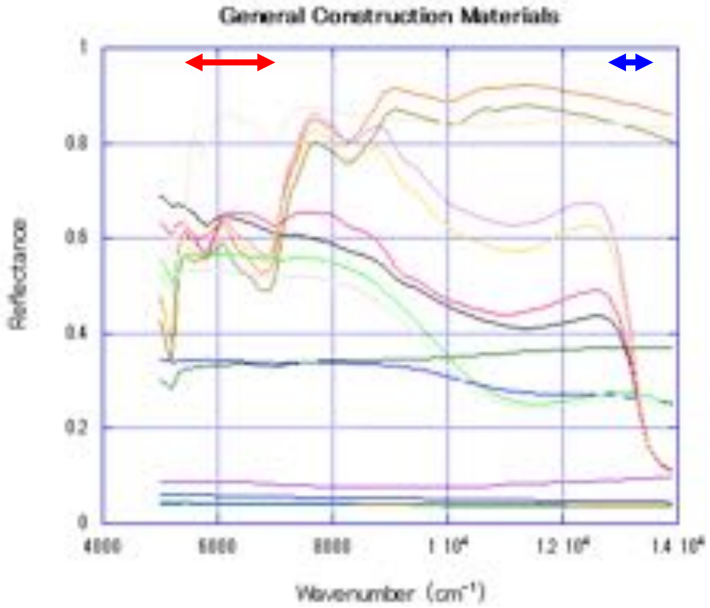


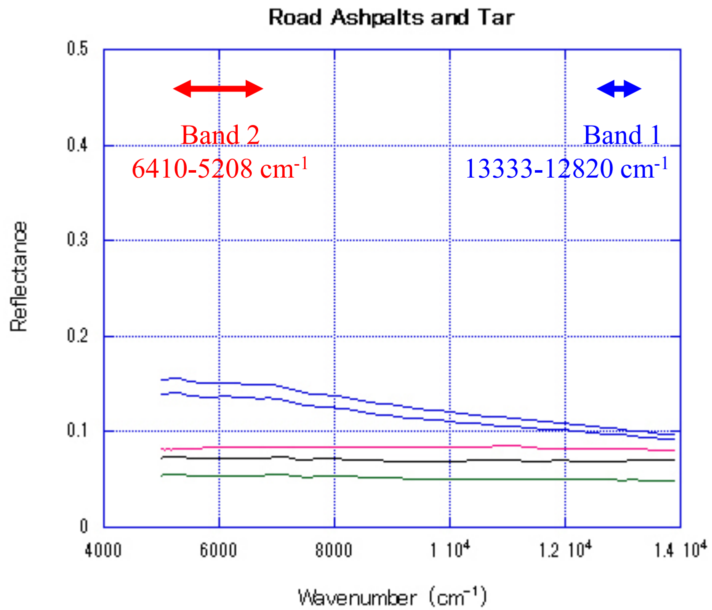
Reflectance (retrieved vs initial values)

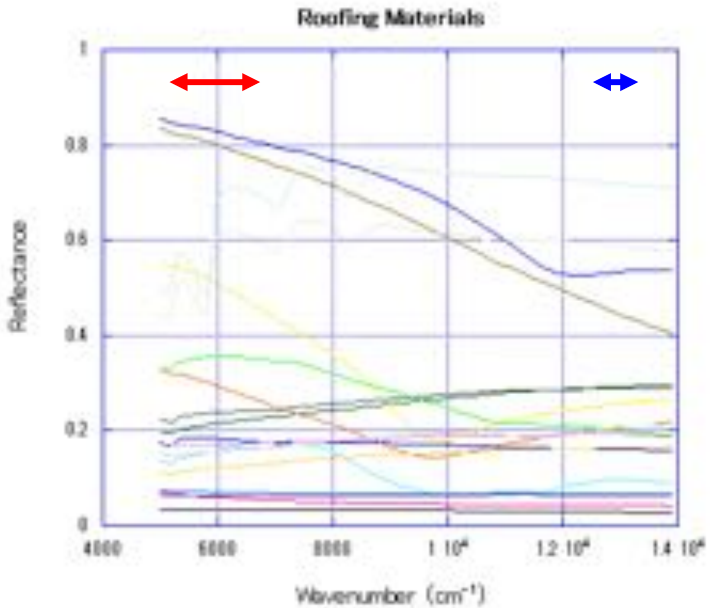


Reflectance of urban materials (ASTER spectral library)

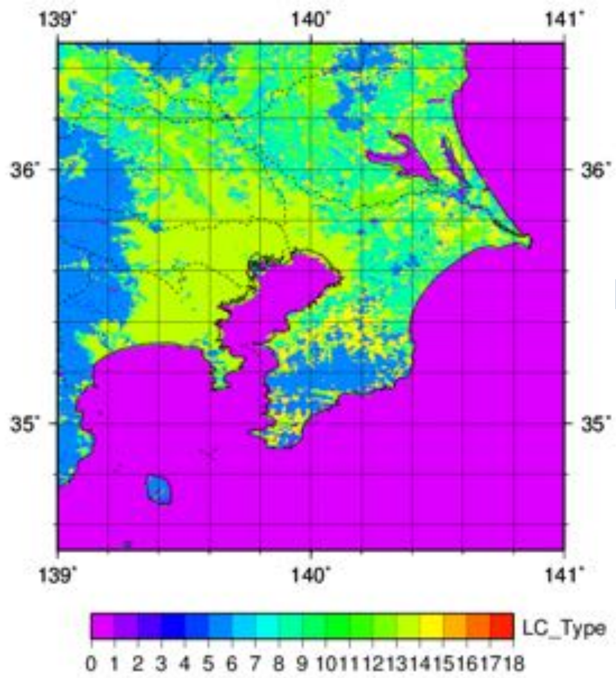








Land cover type

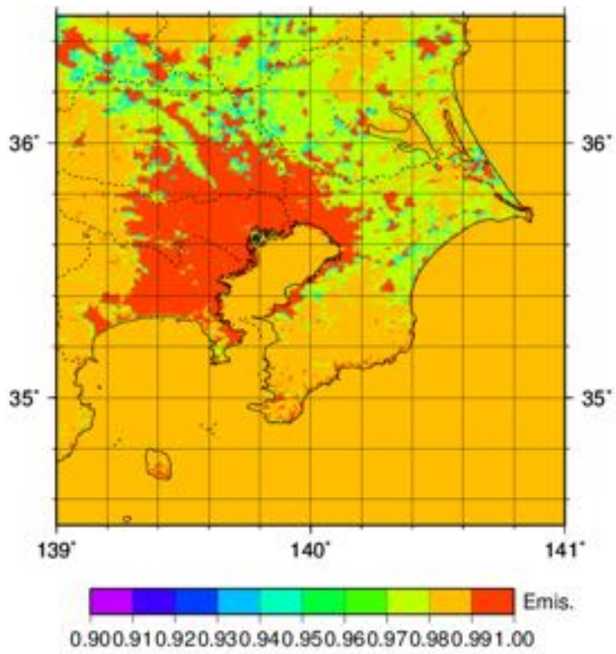


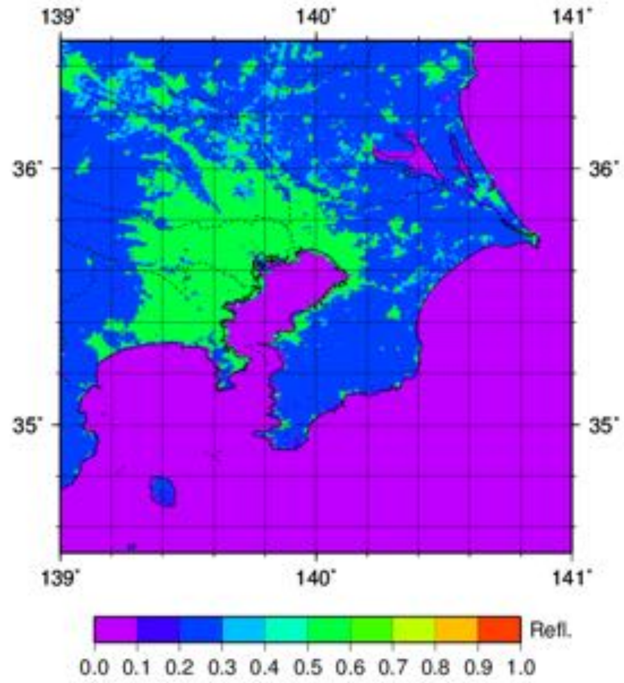
Wilber et al., 1999 (NASA/TP-1999-209362)

Table 4.

Type ID	IGBP type	Spectral library
1	Evergreen Needleleaf Forest	Conifer
2	Evergreen Broadleaf Forest	Conifer
3	Deciduous Needleleaf Forest	Deciduous
4	Deciduous Broadleaf Forest	Deciduous
5	Mixed Forest	1/2 Conifer + 1/2 Deciduous
6	Closed Shrublands	1/4 Quartz sand + 3/8 Conifer + 3/8 Deciduous
7	Open Shrubland	3/4 Quartz sand + 1/8 Conifer + 1/8 Deciduous
8	Woody Savannas	Grass
9	Savannas	Grass
10	Grasslands	Grass
11	Permanent Wetlands	1/2 Grass + 1/2 Seawater
12	Croplands	Grass
13	Urban	Black Body
14	Cropland/Mosaic	1/2 Grass + 1/4 Conifer + 1/4 Deciduous
15	Snow and Ice	Mean Of Fine, Medium, and Coarse snow and Ice
16	Barren	Quartz sand
17	Water Bodies	Seawater
18	Tundra	Frost

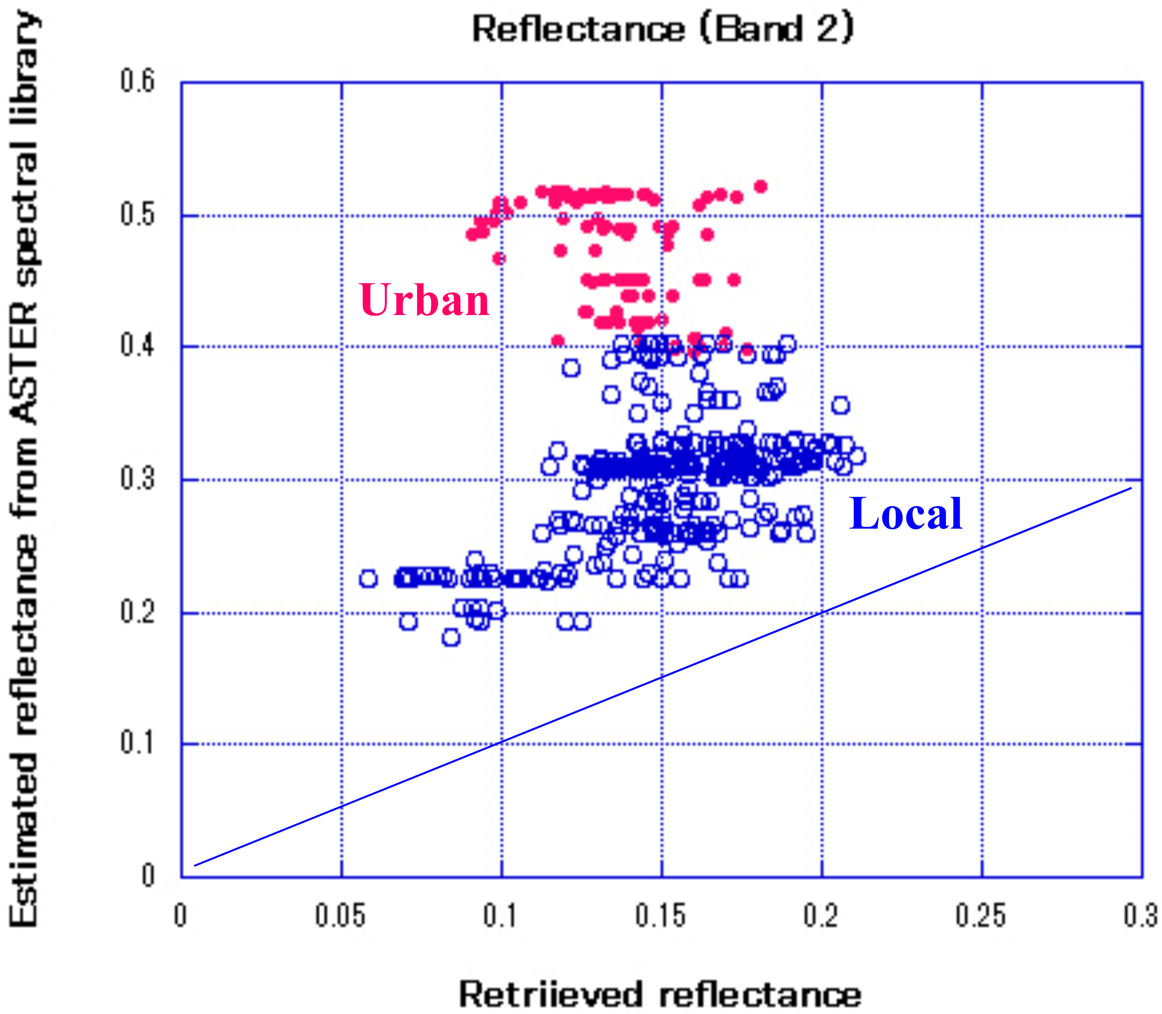
Reflectance (SWIR)

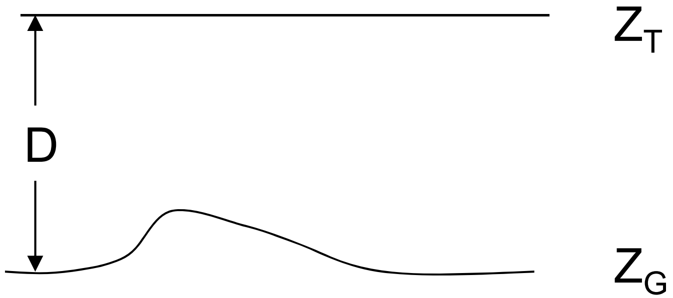




Emissivity (TIR)

Reflectance of urban materials (ASTER spectral library)



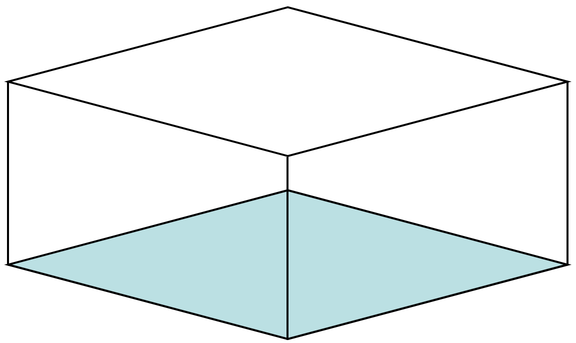


Z_T=5500m (500hPa), 35 layers

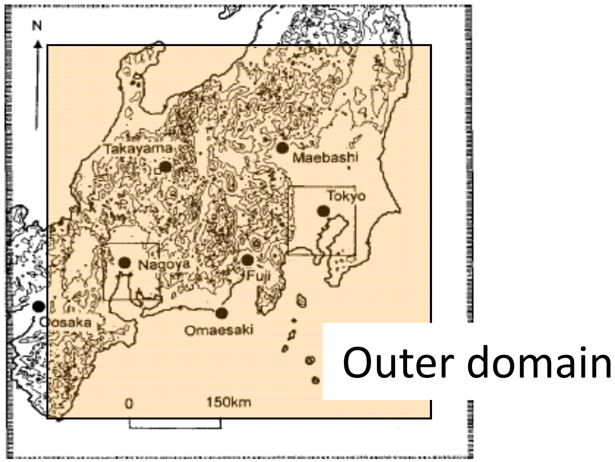
Domain:120km～600km

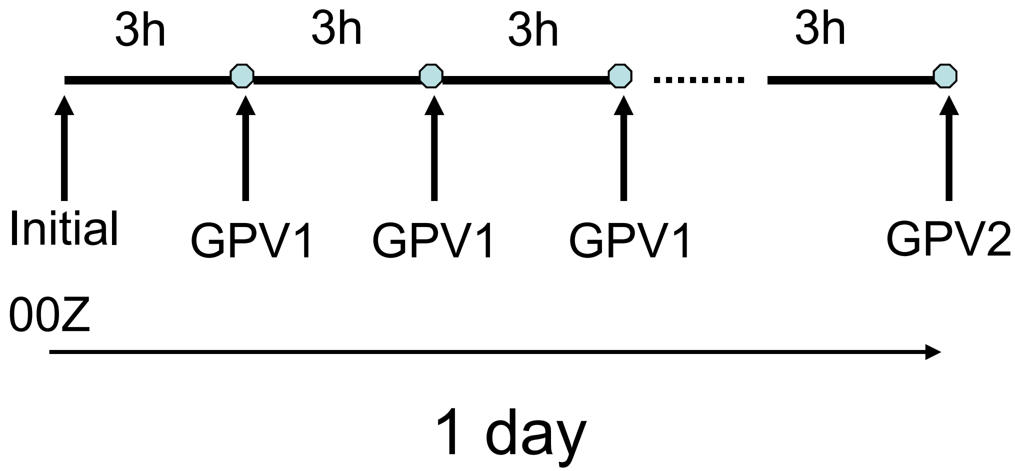
Resolution:1km～10km

Dry model



Nudging with GPV/MSM
(dx=7.5’, dy=5’: for outer domain
GPV data are used every 3 hours)





Basic equations (AIST-MM)

$$\frac{\partial}{\partial t}(Du)+\frac{\partial}{\partial x}(Du^2)+\frac{\partial}{\partial y}(Duv)+\frac{\partial}{\partial s}(D\acute{s}u)-fDv$$
$$=-c_p\Theta D\left\{\frac{\partial \pi}{\partial x}-(s-1)\frac{\partial D}{\partial x}\frac{g\theta}{c_p\Theta^2}\right\}$$
$$+K_H^u D\frac{\partial^2 u}{\partial x^2}+K_H^u D\frac{\partial^2 u}{\partial y^2}+\frac{1}{D}\frac{\partial}{\partial s}\left(K_V^u\frac{\partial u}{\partial s}\right)$$

$$\frac{\partial}{\partial t}(Dv)+\frac{\partial}{\partial x}(Duv)+\frac{\partial}{\partial y}(Dv^2)+\frac{\partial}{\partial s}(D\acute{s}v)+fDu$$
$$=-c_p\Theta D\left\{\frac{\partial \pi}{\partial y}-(s-1)\frac{\partial D}{\partial y}\frac{g\theta}{c_p\Theta^2}\right\}$$
$$+K_H^v D\frac{\partial^2 v}{\partial x^2}+K_H^v D\frac{\partial^2 v}{\partial y^2}+\frac{1}{D}\frac{\partial}{\partial s}\left(K_V^v\frac{\partial v}{\partial s}\right) \tag{2.9}$$

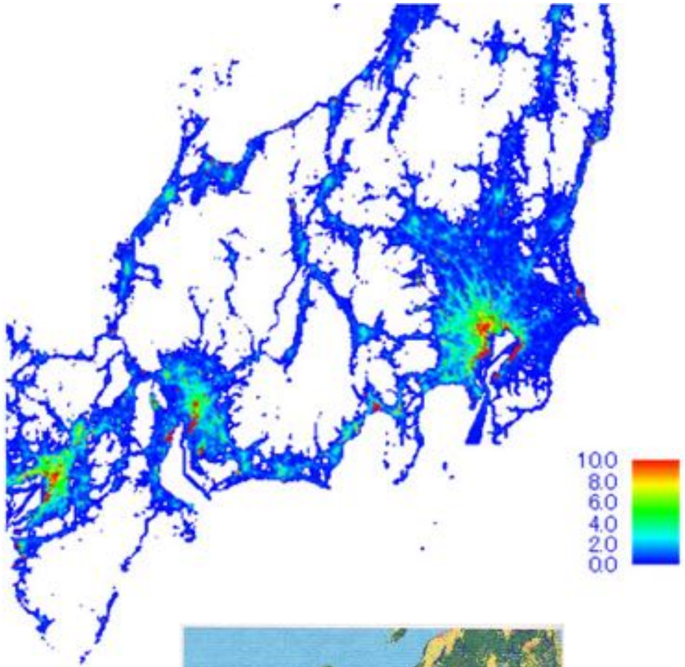
$$\frac{\partial \pi}{\partial s}=\frac{g\theta}{c_p\Theta^2}D \tag{2.10}$$

$$\frac{\partial}{\partial t}(D\theta)+\frac{\partial}{\partial x}(Du\theta)+\frac{\partial}{\partial y}(Dv\theta)+\frac{\partial}{\partial s}(D\acute{s}\theta)$$
$$=K_H^\theta D\frac{\partial^2\theta}{\partial x^2}-K_H^\theta(s-1)\frac{\partial\theta}{\partial s}\frac{\partial^2}{\partial x^2}(\ln D)$$
$$-K_H^\theta\frac{\partial \ln D}{\partial x}(s-1)\frac{\partial}{\partial s}\frac{\partial\theta}{\partial x}$$
$$+K_H^\theta D\frac{\partial^2\theta}{\partial y^2}-K_H^\theta(s-1)\frac{\partial\theta}{\partial s}\frac{\partial^2}{\partial y^2}(\ln D)$$
$$-K_H^\theta\frac{\partial \ln D}{\partial y}(s-1)\frac{\partial}{\partial s}\frac{\partial\theta}{\partial y}$$
$$+\frac{1}{D}\frac{\partial}{\partial s}\left(K_V^\theta\frac{\partial\theta}{\partial s}\right)+D\frac{\partial F}{\partial Z} \tag{2.11}$$

$$\frac{\partial}{\partial x}(Du)+\frac{\partial}{\partial y}(Dv)+\frac{\partial}{\partial s}(D\acute{s})=0.$$

$$s=\frac{z-z_G}{z_T-z_G},$$
$$D=z_T-z_G$$
$$\acute{s}=\left\{w-u\left(\frac{\partial z}{\partial x}\right)-v\left(\frac{\partial z}{\partial y}\right)\right\}\frac{\partial s}{\partial z}.$$

- hydrostatic model
- Terrain following coordinate system



Anthropogenic CO_2 source:

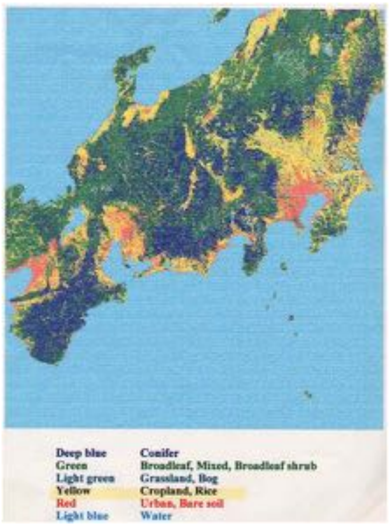
EAGrid 2000 (Kannari et al., 2007)

Natural source and sink

NEP: Net ecosystem production
GPP: Gross primary production
R: Respiration
I: Solar insolation～APAR
(Kondo et al., 2001)

$$NEP = \frac{bI}{1 + aI} - R \qquad Q=2.5$$

$$R = R_1 Q^{\frac{T - T_1}{10}} \qquad R_1=0.102$$

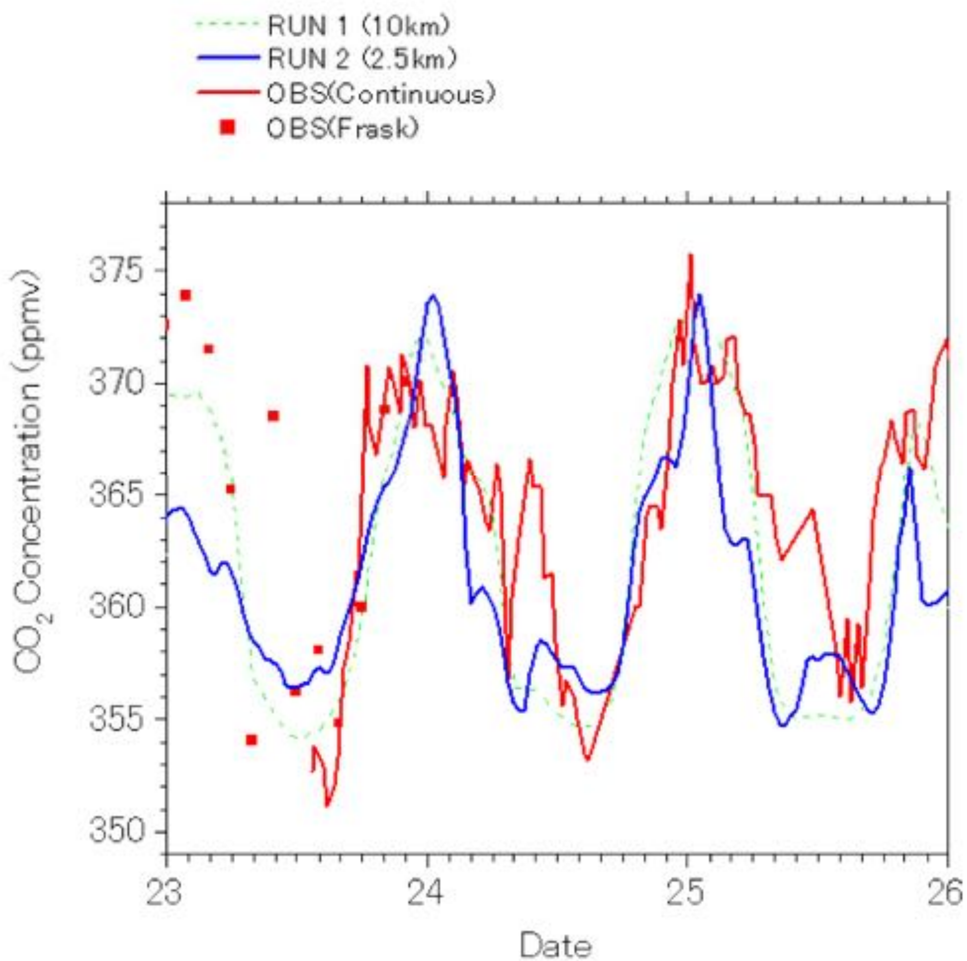


Vegetation map of Japan (Bio diversity center of Japan (2000)

Table 2. a, b and G_S of various plant species

No.	plant species	G_s mms^{-1}	a $J^{-1}\ sm^2 \times 10^{-4}$	b $mgCO_2\ J^{-1} \times 10^{-3}$
1	ever green broad leaf shrub	9.4	6.80	0.79
2	ever green conifers	20.6	6.80	1.71
3	decidous conifers	11.4	6.80	0.95
4	decidous broad leaf tree	20.7	6.80	1.72
5	ever green broad leaf tree	12.1	6.80	1.01
6	mixed forest	13.8	6.80	1.15
7	temperate grass land	23.0	6.80	1.92
8	bog	5.0	6.80	0.42
9	arable cropland	32.5	6.80	2.70
10	rice	25.1	6.80	2.08

Comparison at TKY (2000)

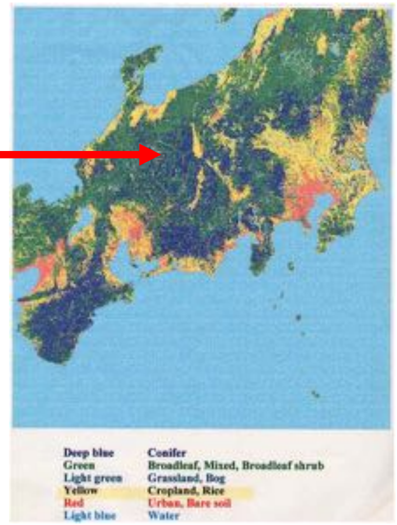


July (2000)

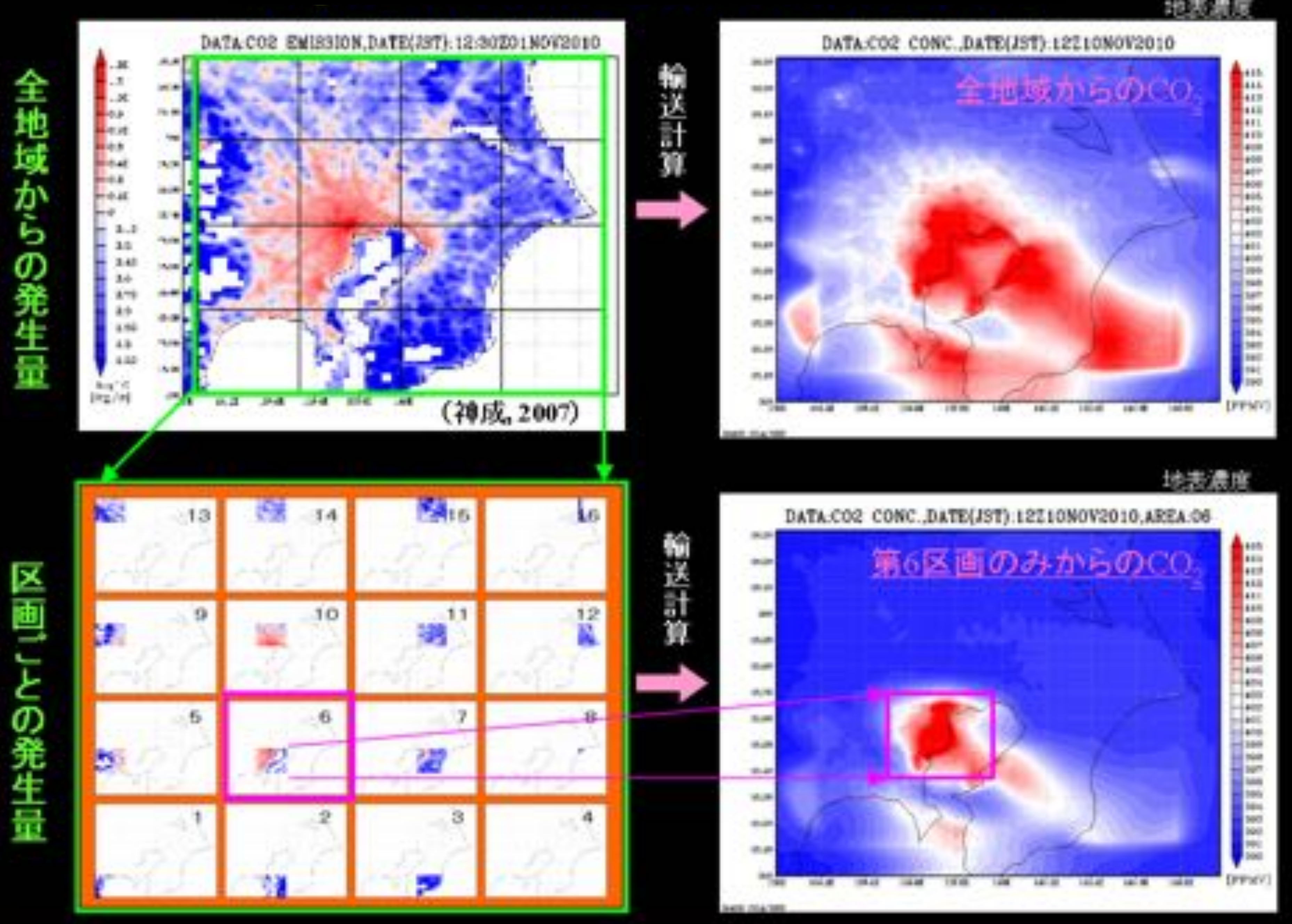
TKY flux tower (Takayama city)

TKY

http://asiaflux.yonsei.ac.kr/



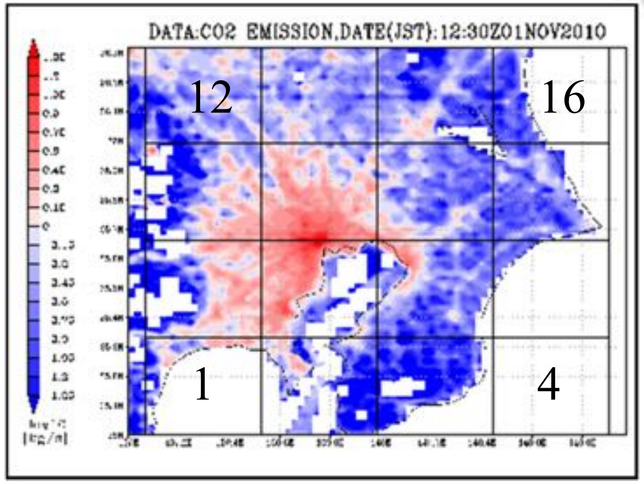
Basic calculations for synthesis inversion

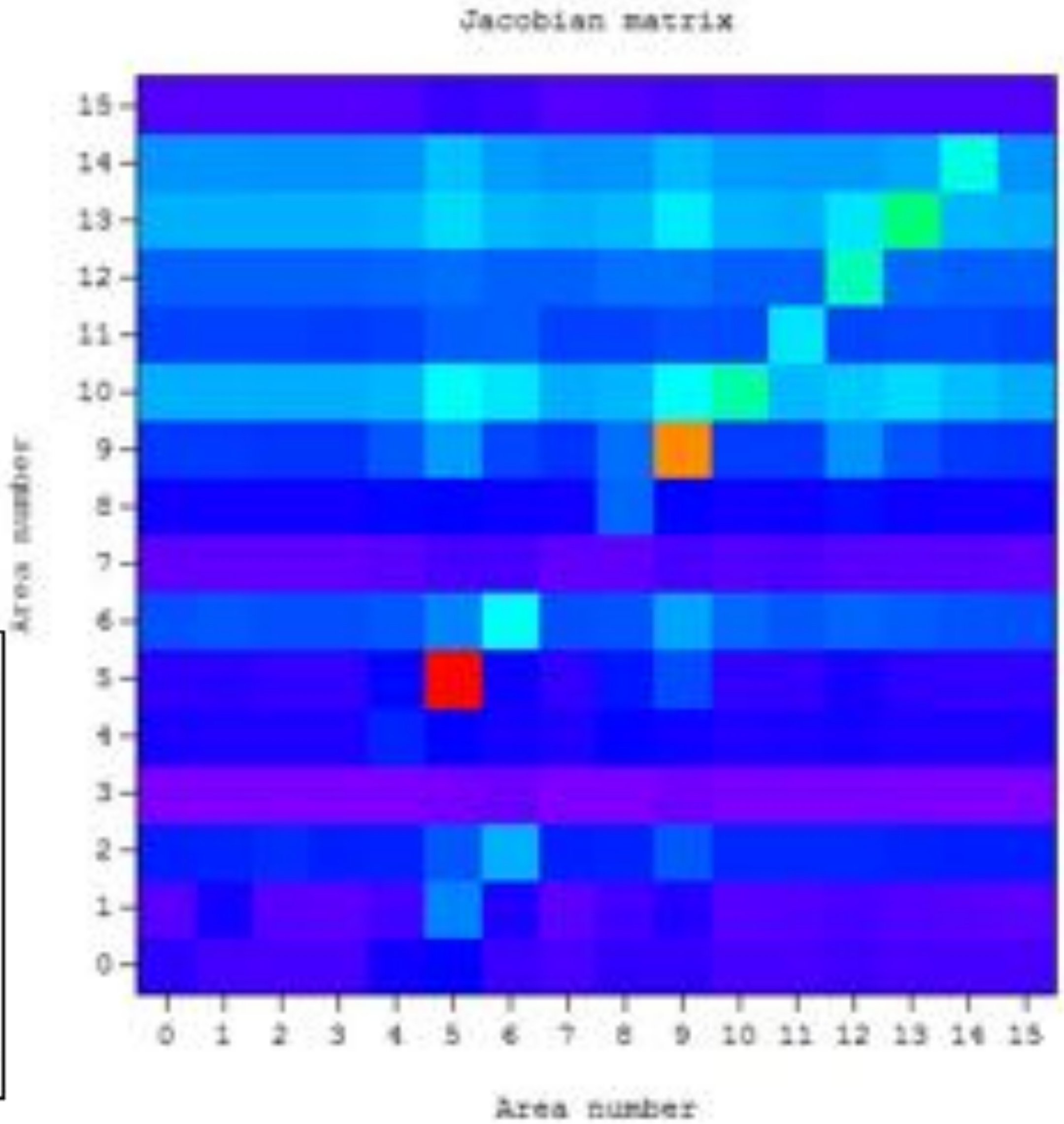


20-720x480-wmv.wmv

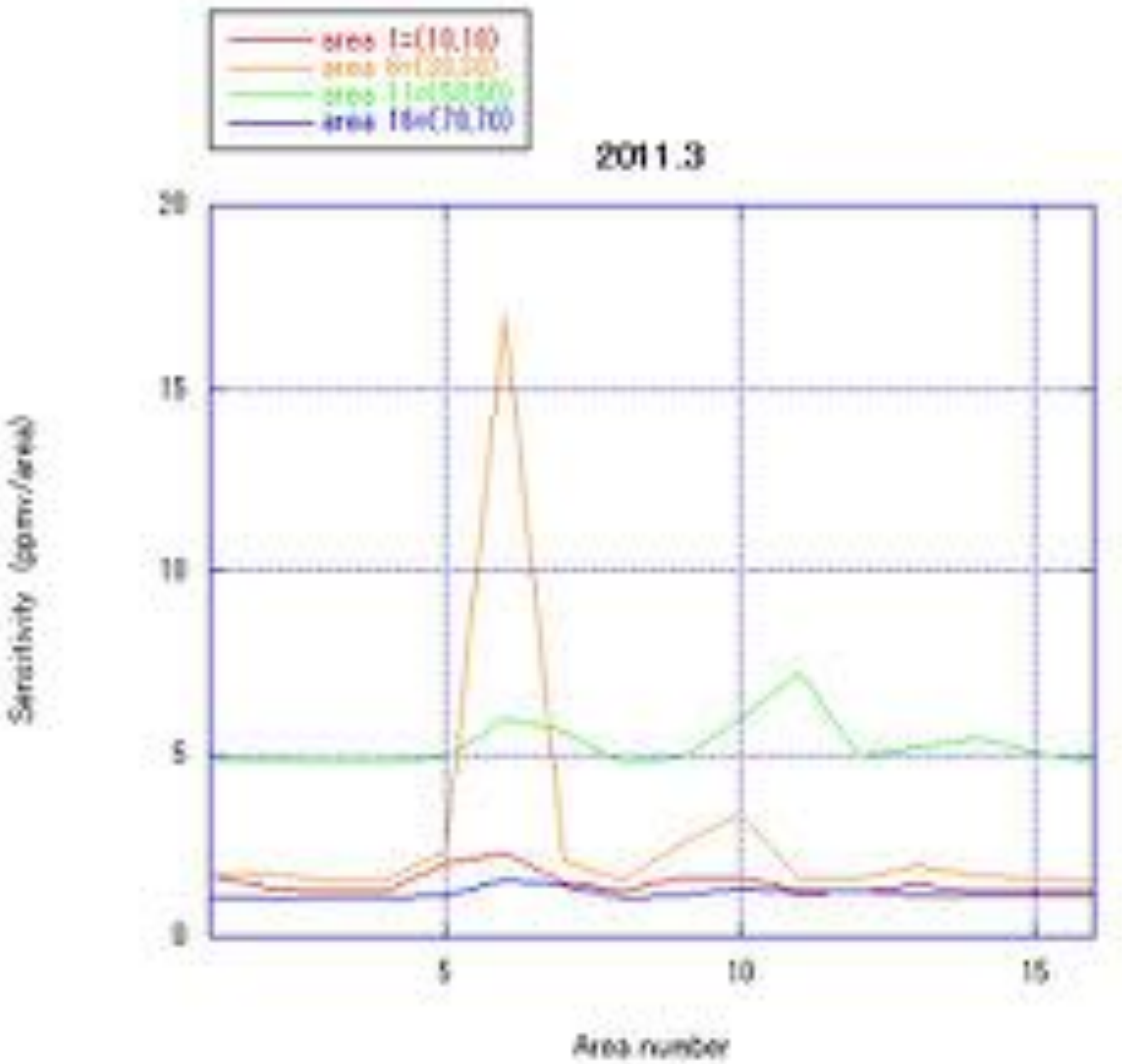
Example of a Jacobean matrix used for synthesis inversion analysis

- case for 2011.3
- only surf. data were used
- all hourly data were used
- assumed that there is one observation site in each block area
- observational error is infinite

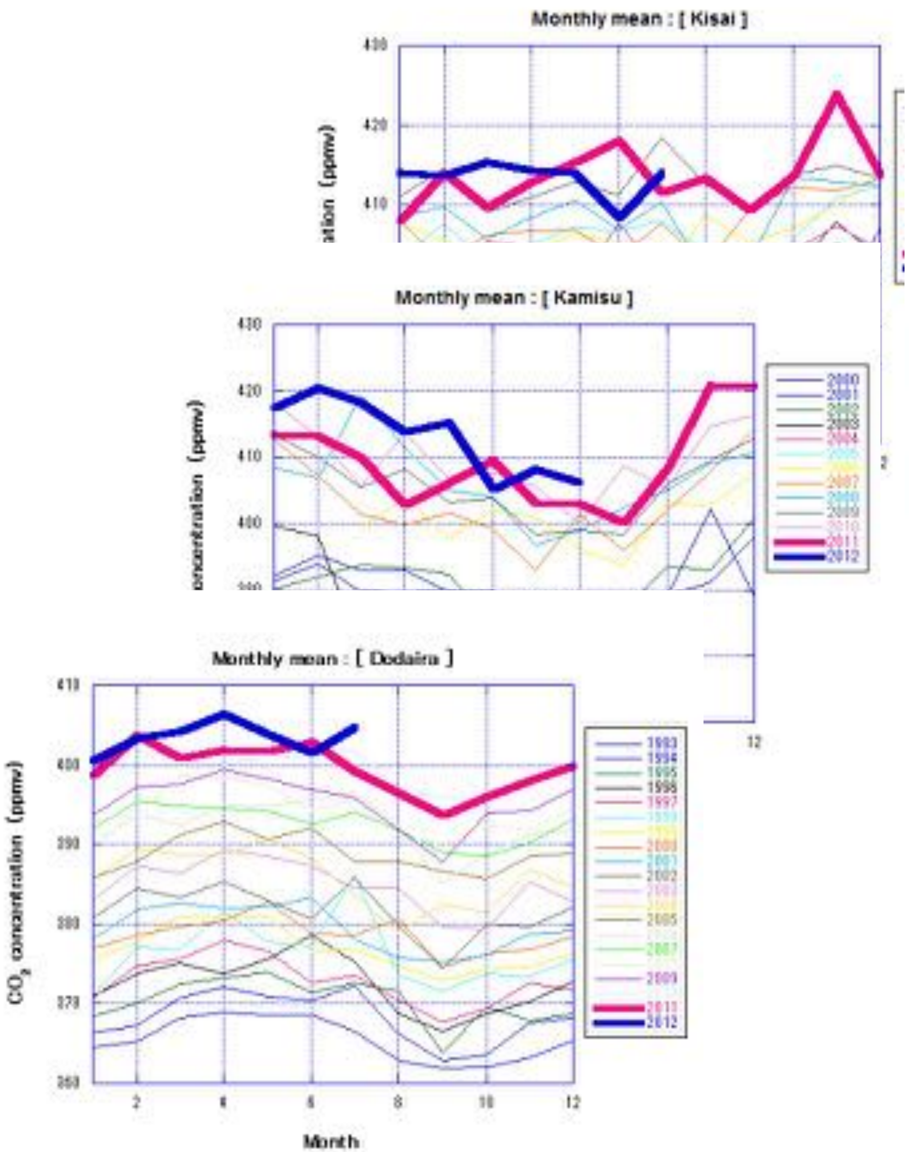


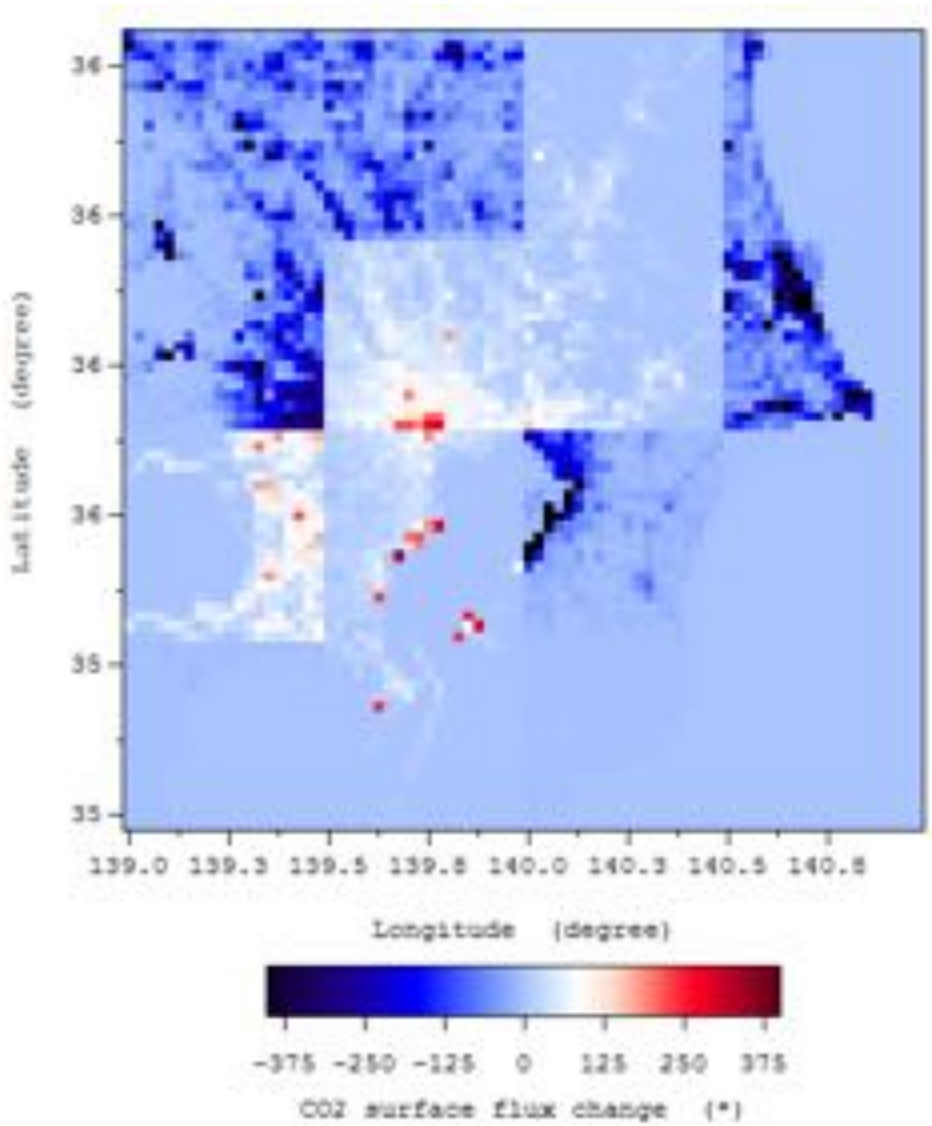


Example of horizontal resolution functions



Result from synthesis inversion analysis using AIST-MM
(monthly average for 2011.3; only surface data were used)



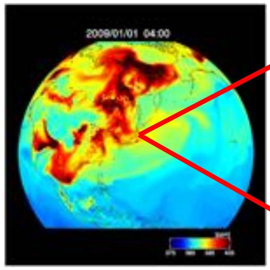


CO_2 transport simulation & inversion analysis

R. Imasu, Y. Arai (Univ.Tokyo), H. Kondo (AIST), and Y. Niwa (MRI/JMA)

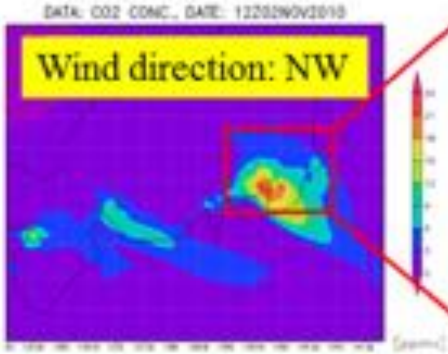
Global → Regional (urban area)

NICAM-TM



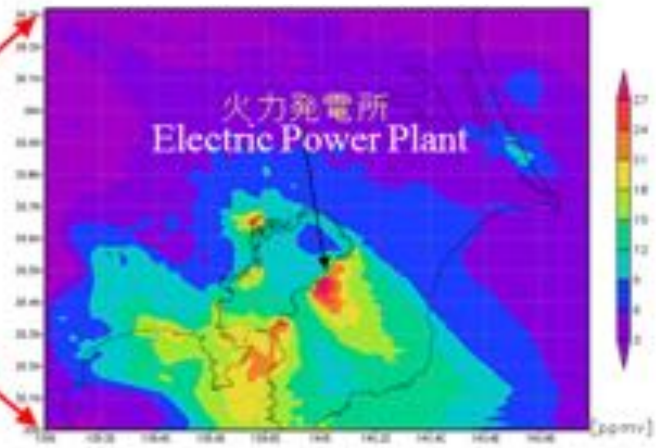
By Y. Niwa

AIST-MM

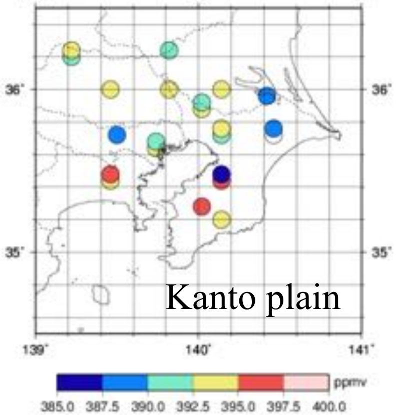


By Y. Arai and H. Kondo

Max. resolution = 1km x 1km

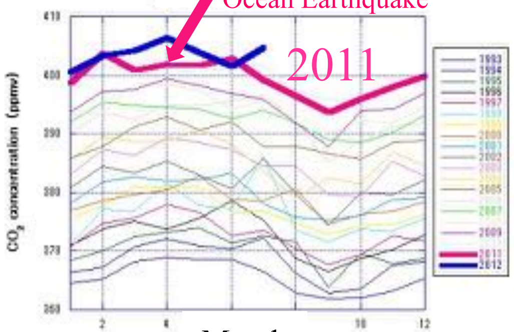


GOSAT
targeting observation



+

Ground-based
in situ measurements



(Data: Dodaira/WDCGG)

→

Inversion
(synthesis)

Changes
in emission strength