Constructing a Carbon Flux Estimation System with Bias Corrected Satellite Data

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Today's presentation

1. Background
2. Satellite data features and bias correction
3. Inverse model experiment
4. Summary and conclusions

1. Background

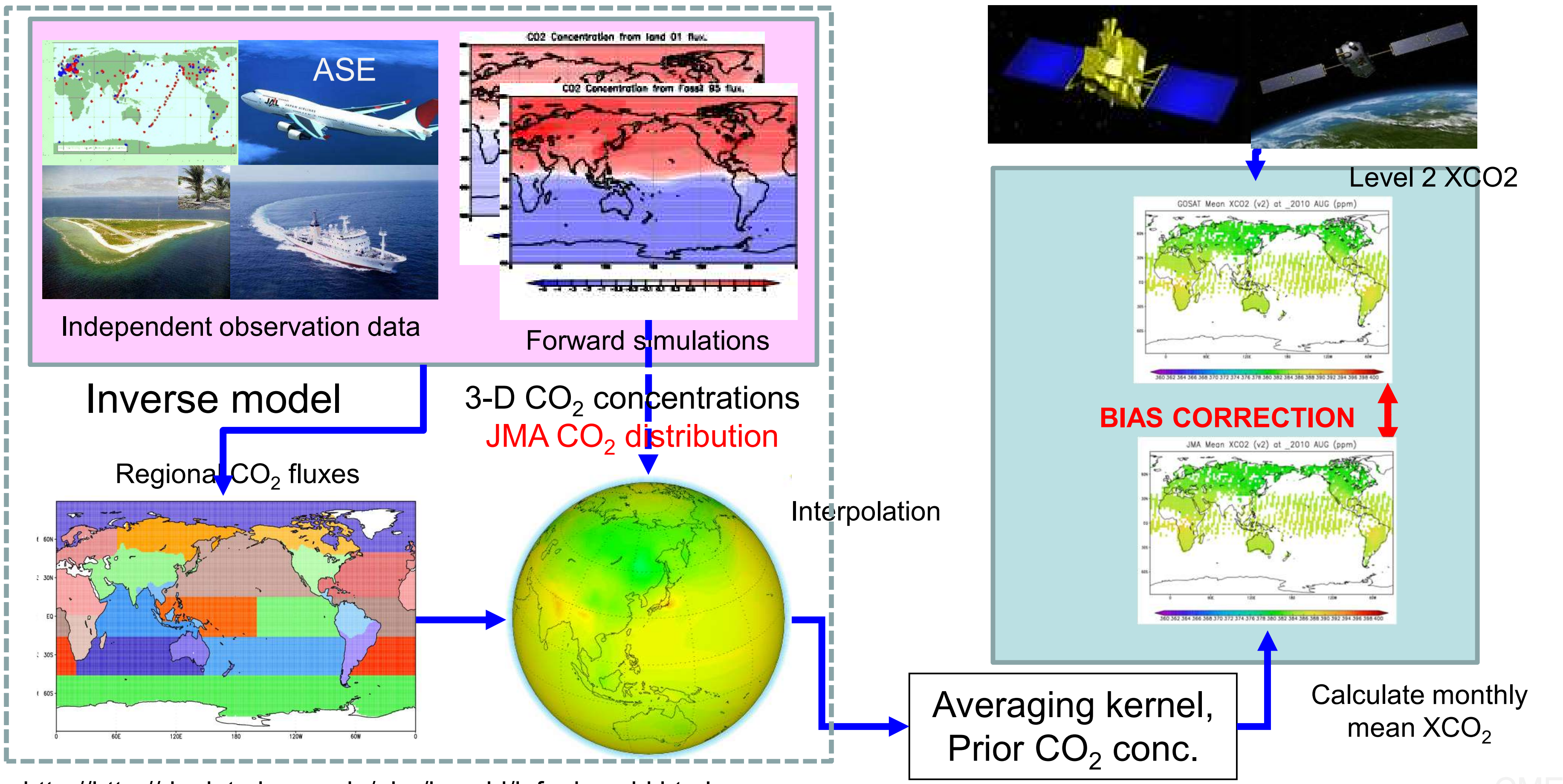
- The merits of satellite data in carbon cycle analysis include their large spatial coverage and relatively large space representativeness comparing with in-situ observations.

- However, there are non-trivial points that need to be reconsidered in satellite data. An important issue is bias, which may change with time and space. Recently, New data were released to public (GOSAT SWIR L2 Ver. 2.8).

- To make use of satellite data (GOSAT1-2, OCO-2, TanSat, …) in carbon cycle analysis, bias evaluation and correction (horizontal and temporal) is one of the critical issue.

- We evaluated bias of GOSAT SWIR Level 2 Ver. 2.7 and 2.8. We also tried to modify their bias and introduce corrected data to our inversion system.

1-2. Concept of our analysis system



http://http://ds.data.jma.go.jp/ghg/kanshi/info_kanshi.html

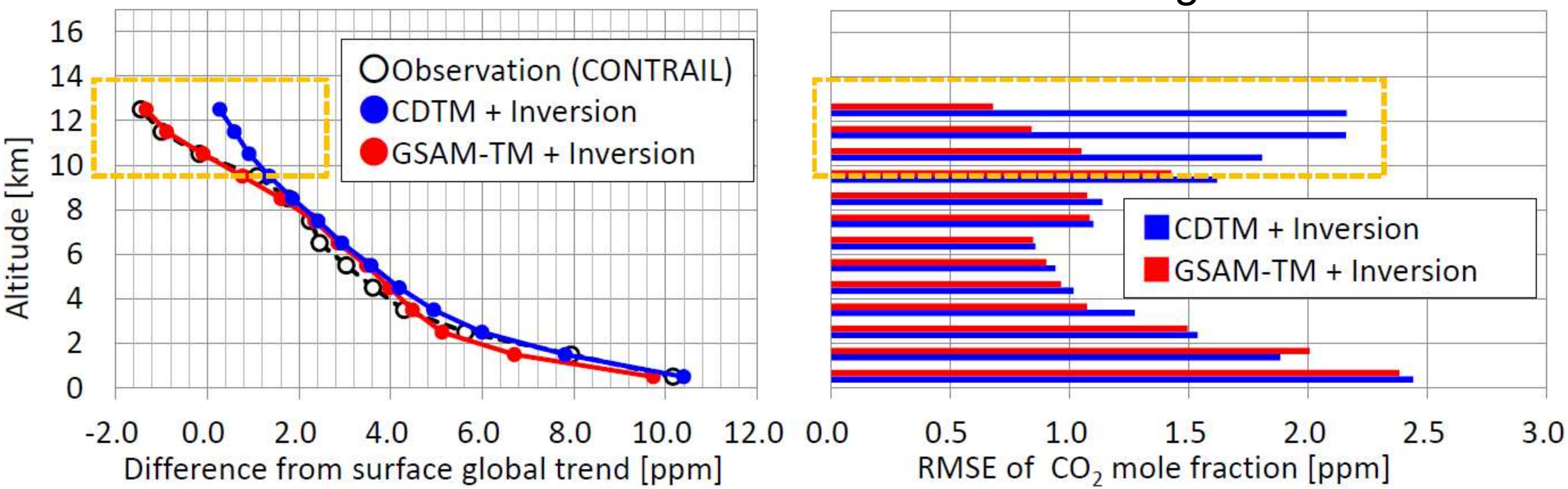
We calculate almost 9 year's GOSAT L2 bias by comparing with independent XCO2 analysis.

1-2. Independent CO2 analysis (JMA-CO2)

Specification of JMA CO2 distribution	
Analysis period	1985 – 2016 (Monthly)
Analysis Method	Bayesian Synthesis Inversion (TransCom 3)
Observation data	Surface, Ship and Aircraft (WDCGG)
Observation error	Difference from smoothed data
Observation data selection	Repeat inverse analysis
Number of region divisions	22 (TransCom 3)
Transport model	GSAM-TM (on-line)
Transport model resolution	TL95L60
Meteorological field	Nudged towards JRA-55
Prior flux	CDIAC, CASA, JMA Ocean analysis

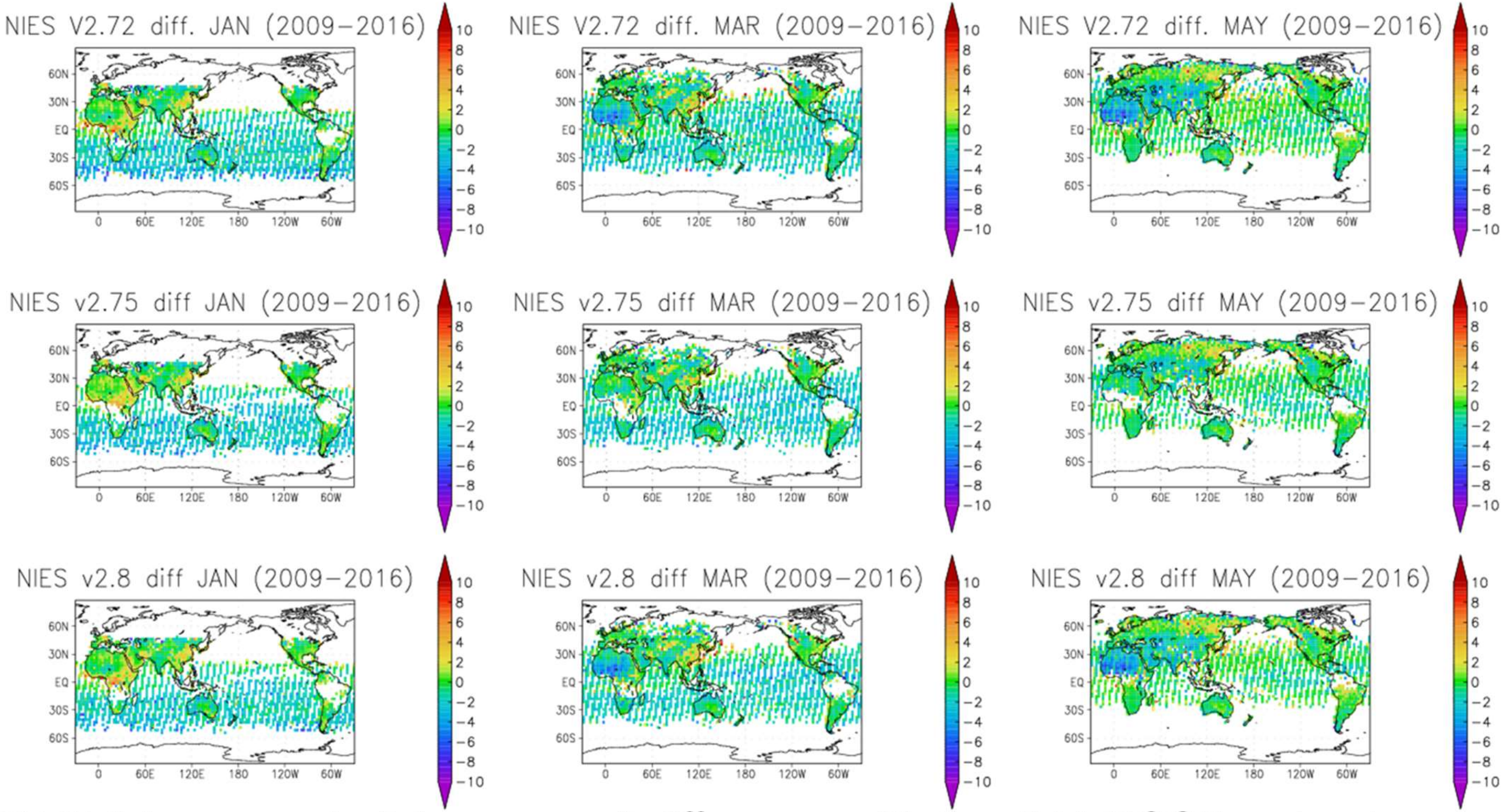
We have been conducting carbon cycle analysis for over 30 years using in-situ observations (surface, ship and aircraft).

Considering the averaging kernel of GOSAT observations, large RMSE near the surface are not a big issue.



Comparison with independent observation (CONTRAIL)（Nakamura et al., TransCom meeting 2018）

2-1. NIES L2 products against JMA XCO2



V2.75 (bias corrected) has a small difference with the JMA XCO2 on land compared to V2.72.

In V2.72 grid points (2.8°) with a large difference from JMA analysis values are more than V2.75 and V2.8.

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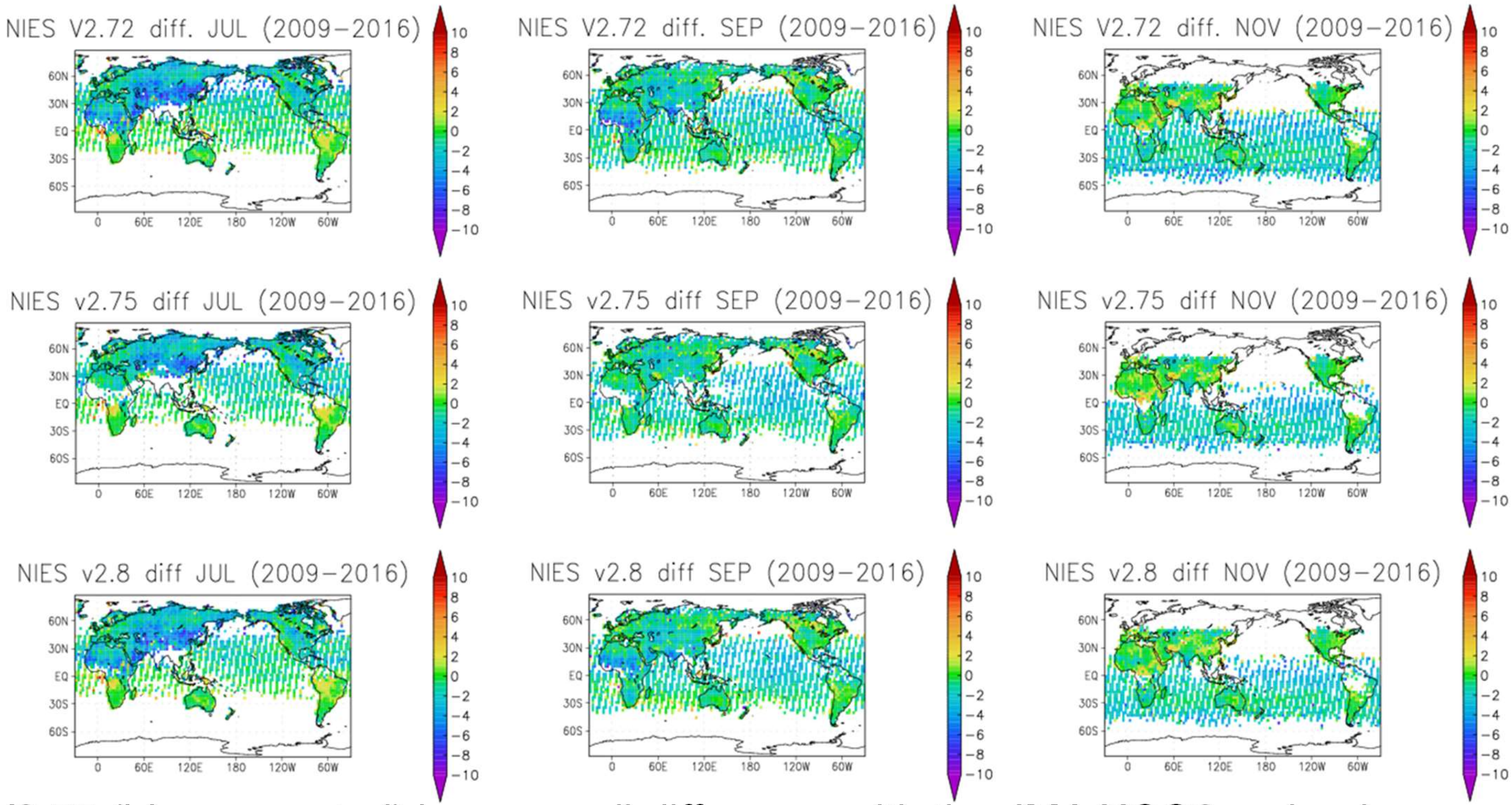

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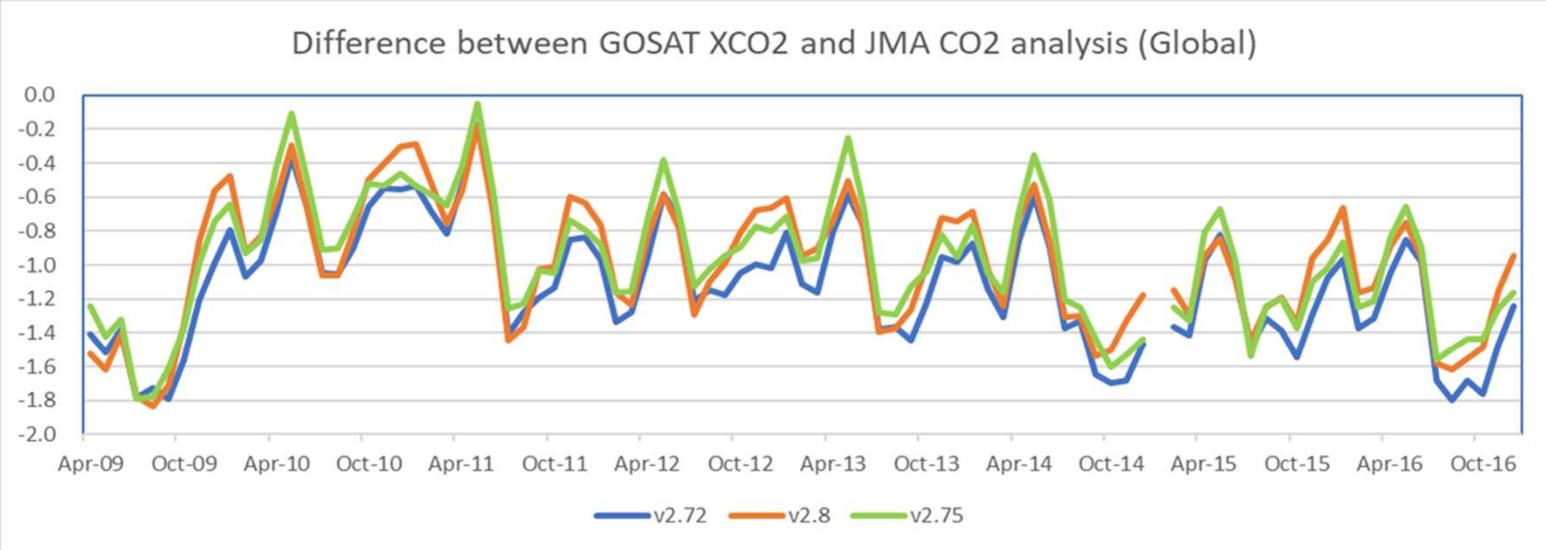
2-3. NIES SWIR L2 products Summary



Ver.	Global	Land	Ocean	N. Land	Tr. Land	S. Land	N. Ocean	Tr. Ocean	S. Ocean
2.72	-1.11	-0.88	-1.17	-0.93	-0.94	-0.59	-0.30	-1.17	-0.92
2.8	-0.99	-0.68	-1.17	-0.74	-0.78	-0.38	-0.19	-1.29	-0.67
2.75	-0.97	-0.45	-1.52	-0.61	-0.06	-0.39	-0.46	-1.66	-0.98

In global scale, there is no significant trend in the difference between GOSAT L2 XCO2 and JMA XCO2. We assumed that 10 year's difference as a bias of GOSAT L2 XCO2.

The V. 2.75 and V. 2.8 difference is smaller than V. 2.75 especially land region.

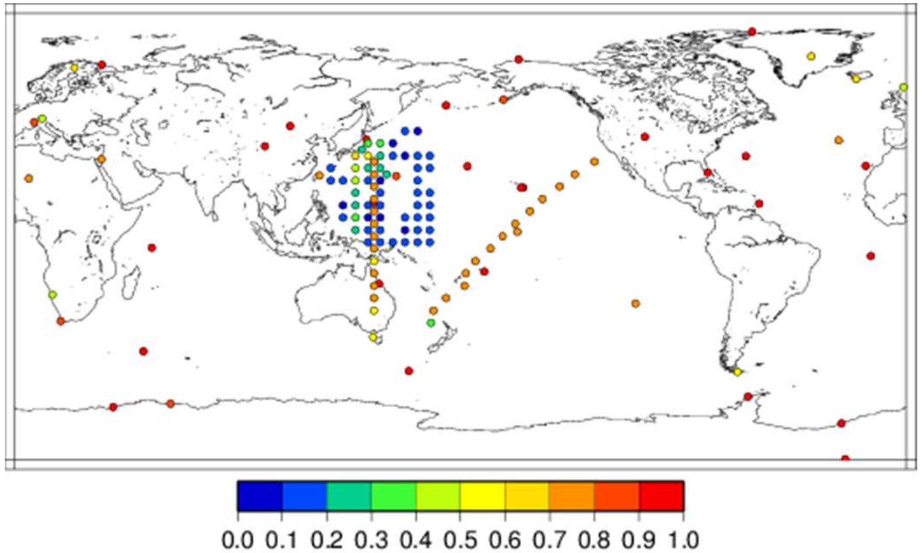
3-1. Inverse model experiments

Common settings	
Analysis Period	1985 – 2017
Inverse model	Bayesian Synthesis
Region Number	22
Transport model	GSAM-TM (TL95L60)
Meteorology	JRA-55
Prior Flux	CDIAC, CASA, JMA Ocean
In-situ observation	WDCGG (-150 sites)

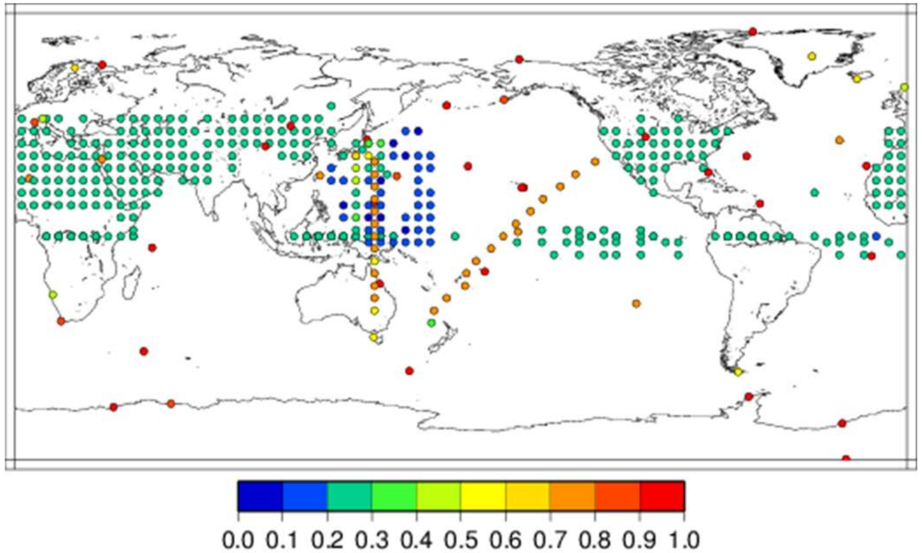
Experiment	CNT	SAT2	SAT3	SAT4	SAT5	SAT6
Bias corrected GOSAT V2.8 uncertainty	-	2ppm	3ppm	4ppm	5ppm	6ppm

3-2. Observation network

CNT case



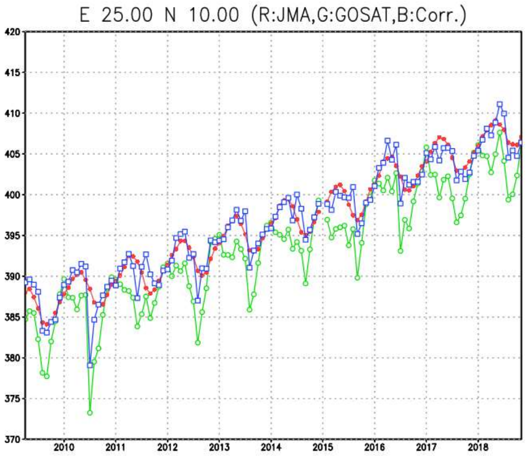
SAT2 - 6 case

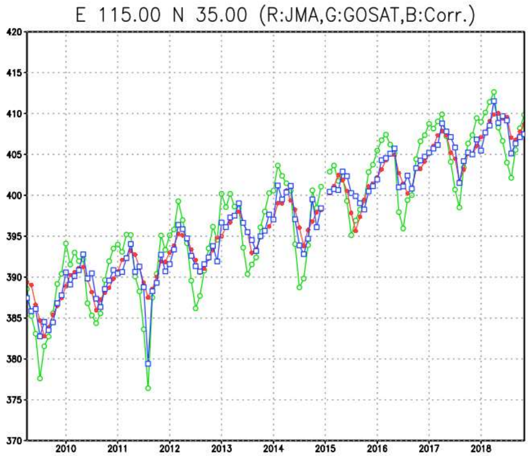


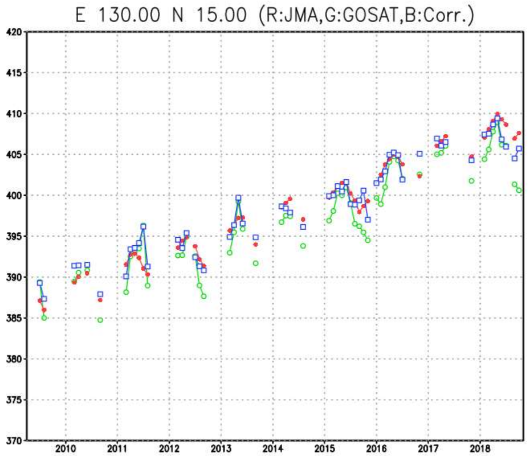
We produced super-observation of 5 degree grid point for GOSAT XCO2 data (The spatial resolution dependency of the bias was small).

We selected almost 310 GOSAT L2 XCO2 data where we can obtain 60% available data in GOSAT observable period (2009/04-2017/12).

3-3. Bias corrected satellite data



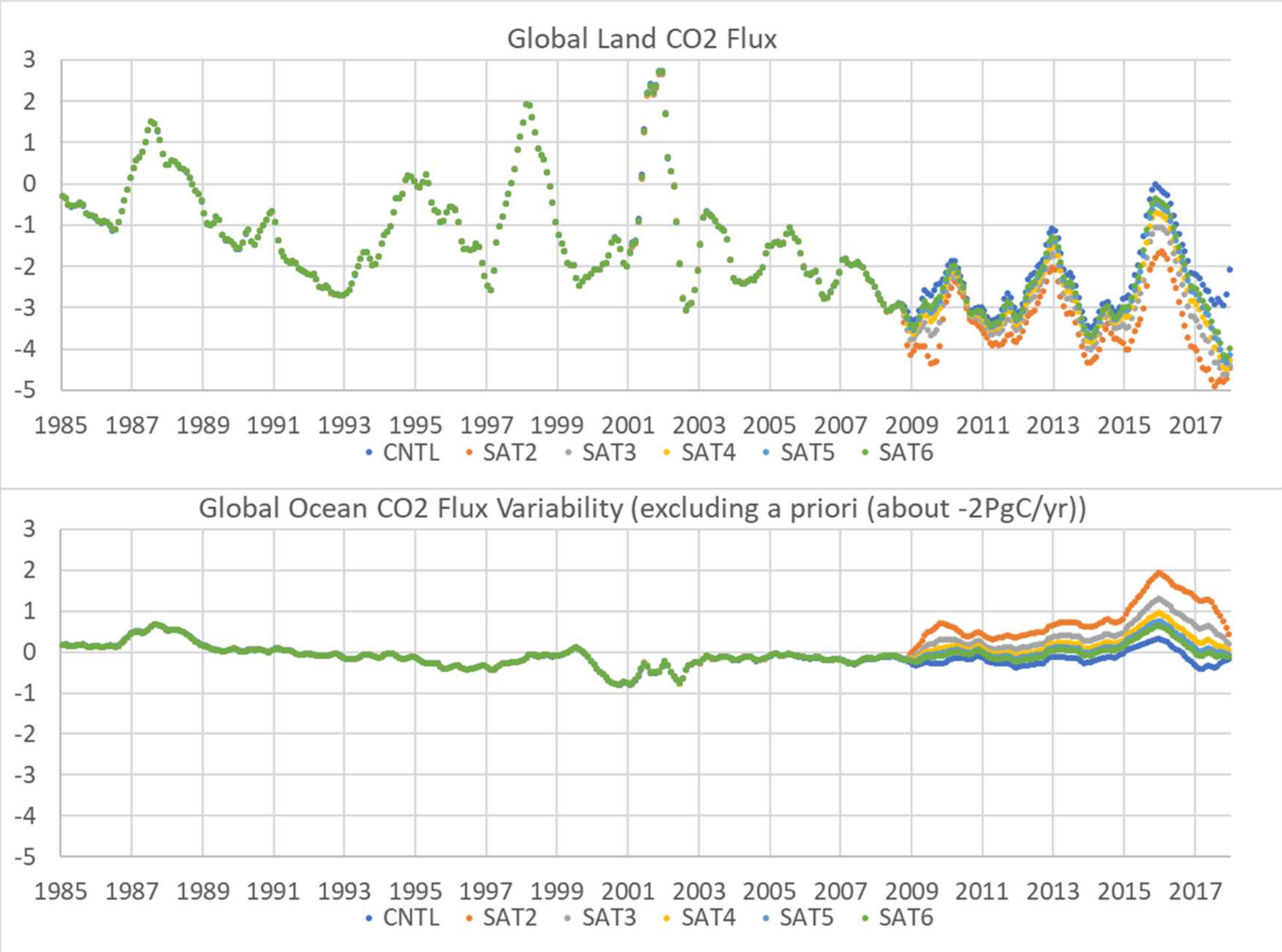




Seasonal-spatial bias corrected satellite data (blue line) distribute around JMA XCO2 (red line).

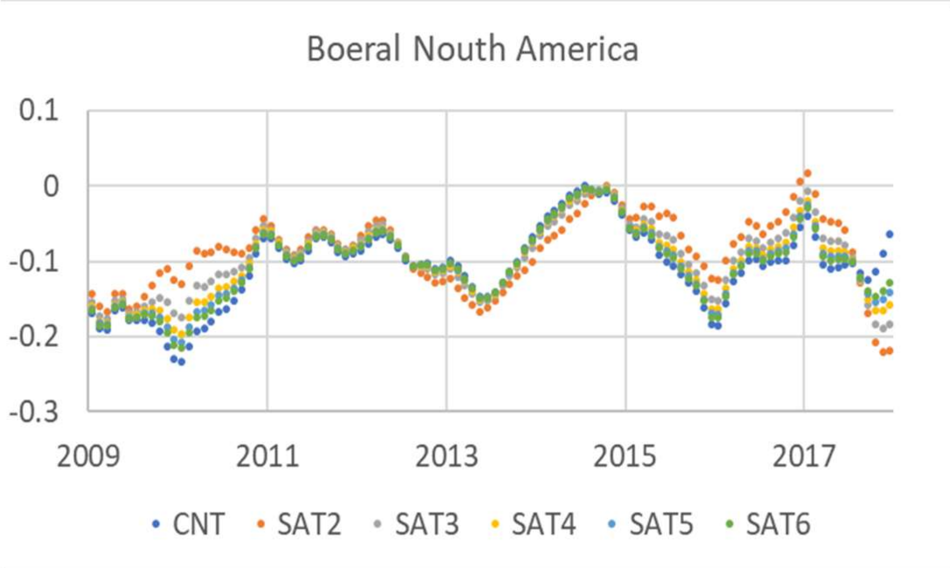
It seems that the signal of yearly fluctuation does not disappear after bias correction.

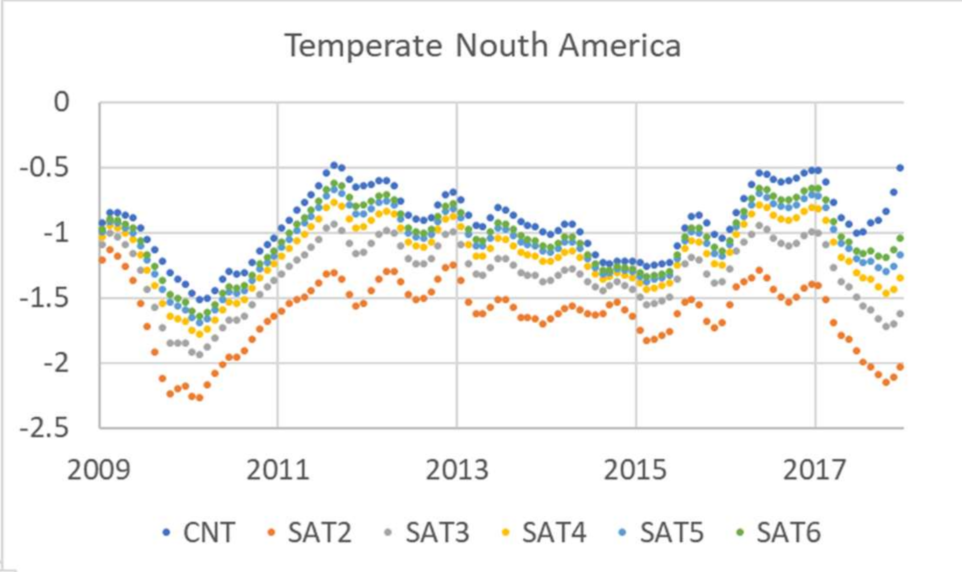
3-4. Estimated Global CO2 Flux

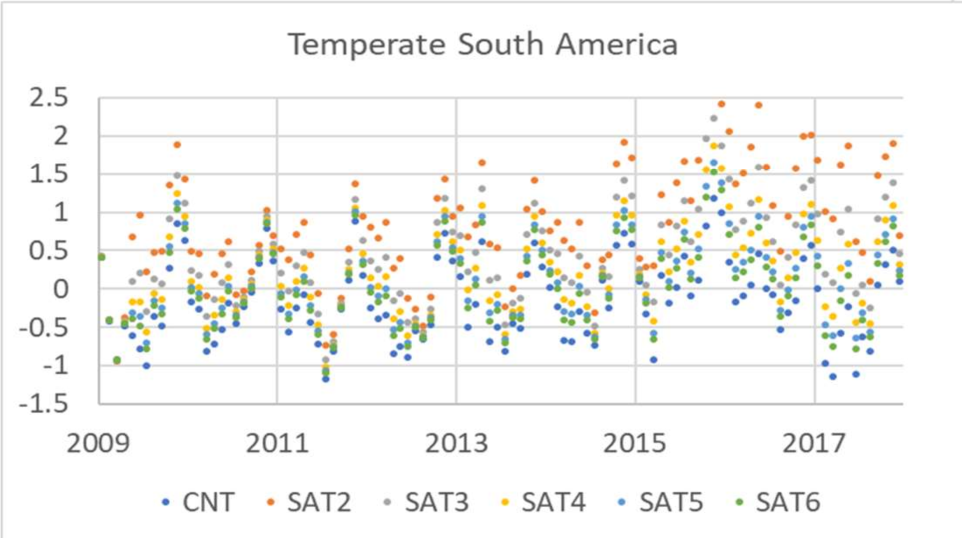


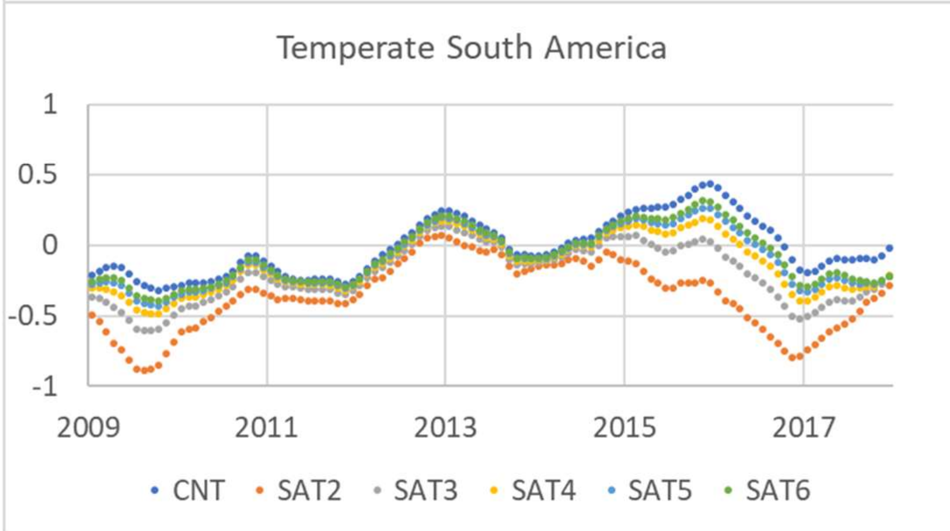
There are some differences in the results of each experiments after the introduction of satellite observation.

3-5. Estimated Regional CO2 Flux (1)



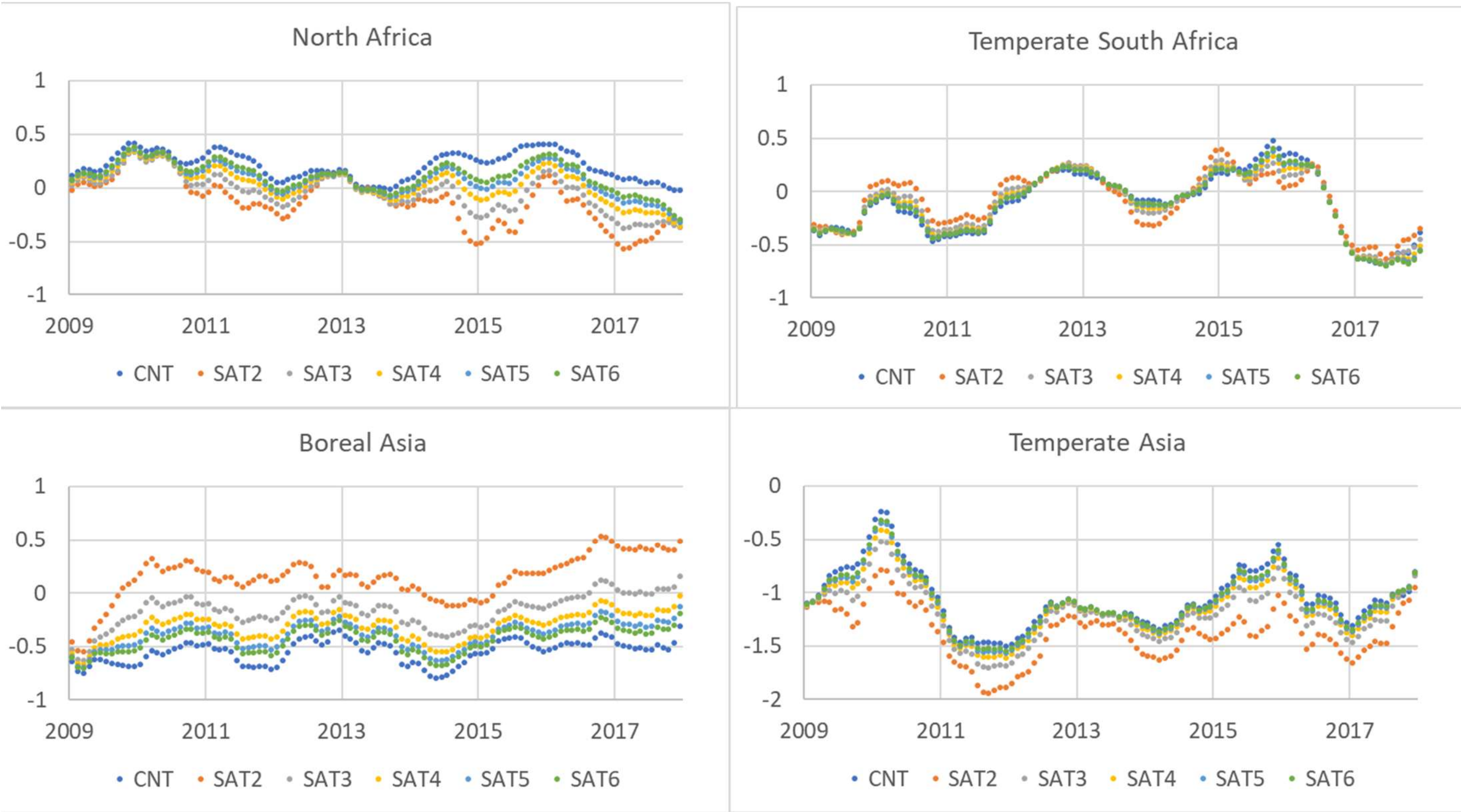






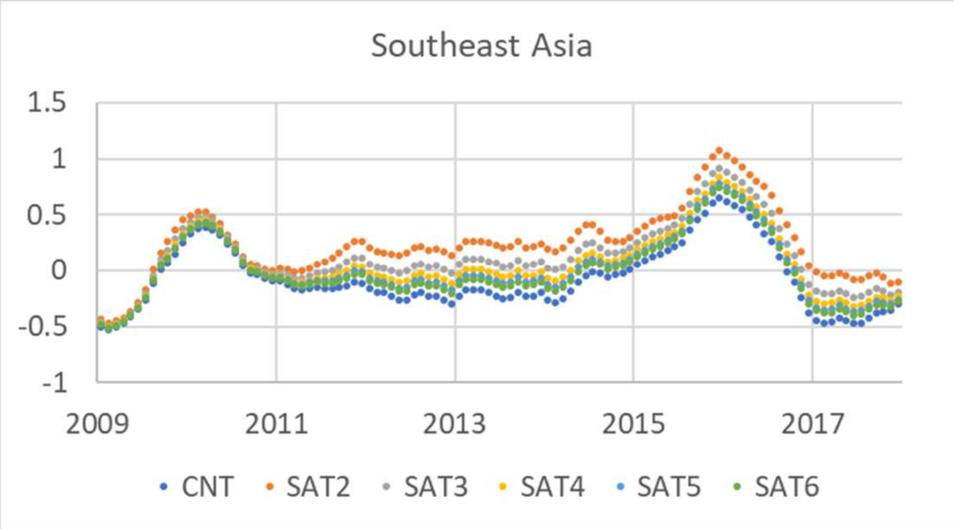
Fluctuations in the carbon balance were seen in relatively weakly constrained areas (temperate North America and Tropical South America).

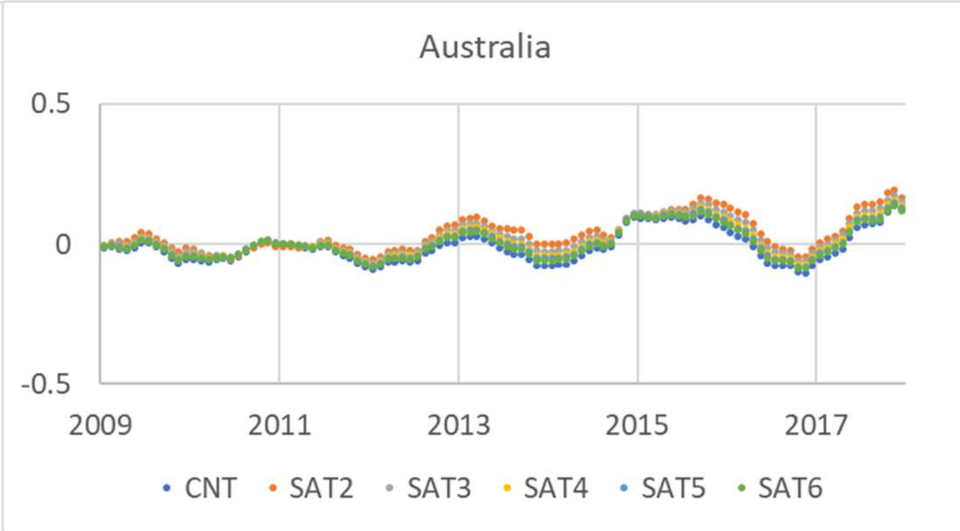
3-6. Estimated Regional CO2 Flux (2)

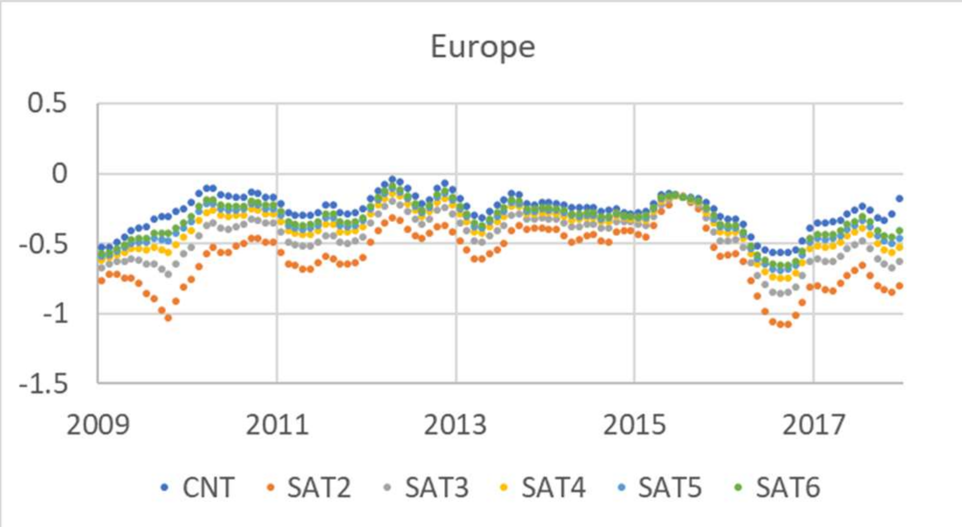


Fluctuations in the carbon balance were seen in relatively weakly constrained areas (North Africa and temperate South Africa).

3-7. Estimated Regional CO2 Flux (3)







Large-scale forest fires that occurred in Southeast Asia in the fall of 2015 could not be well captured due to the small number of satellite observation data.

3-8. Global CO2 flux

PgC/yr	Total Land	Total Ocean	N. Land	Tr. Land	S. Land	N. Ocean	Tr. Ocean	S. Ocean
CNT	-2.88	0.68	-0.09	-0.10	0.04	-0.09	-2.30	-0.14
SAT2	-3.46	0.42	-0.33	0.14	0.39	0.34	-3.38	0.86
SAT3	-3.17	0.42	-0.22	0.04	0.25	0.18	-2.97	0.47
SAT4	-3.17	0.42	-0.22	0.04	0.25	0.18	-2.97	0.47
SAT5	-2.99	0.52	-0.15	-0.04	0.14	0.03	-2.62	0.13
SAT6	-2.96	0.56	-0.14	-0.06	0.11	0.00	-2.54	0.05

Ocean flux exclude a priori (about -2PgC/yr).

Estimated CO2 flux changed even introducing bias corrected satellite data due to satellite data distribution in limited region (tropical – mid latitude land area).

The results suggest that we should cover satellite data globally in carbon cycle analysis.

3-9. Large uncertainty reduction area

	L02	L03	L04	L05	L06	L08	L11
SAT2	-6.3%	-11.8%	-8.8%	-8.2%	-8.9%	-5.2%	-3.6%
SAT3	-3.2%	-6.4%	-4.5%	-4.5%	-4.6%	-2.5%	-1.8%
SAT4	-1.9%	-3.9%	-2.7%	-2.7%	-2.8%	-1.5%	-1.1%
SAT5	-1.2%	-2.6%	-1.8%	-1.8%	-1.9%	-1.0%	-0.7%
SAT6	-0.9%	-1.9%	-1.3%	-1.3%	-1.3%	-0.7%	-0.5%

L02: Temperate N. America, L03: Tropical S. America, L04: Temperate S. America, L05: N. Africa, L06: S. Africa, L08: Temperate Asia, L11: Europe

Uncertainty in flux estimation decreased in tropical to mid-latitude land areas with large numbers of satellite observation data comparing with CNT experiment.

Due to the effect of averaging kernel, satellite observation data has less influence per observation data than in-situ observation data.

4-1. Summary and conclusions

We constructed satellite bias correction scheme making use of independent analysis (JMA CO_2 distribution).

Our results suggested that NIES V2.75 and 2.8 shows smaller difference against independent XCO2 analysis.

We introduced bias-corrected satellite observation data into our inversion system. Estimate CO2 flux is sensitive for satellite data uncertainty due to uneven distribution of satellite data.

At the regional scale, we could strongly constrain tropical and temperate land area except southeast Asia by introducing bias corrected satellite data.

We should make use of satellite data globally in carbon cycle analysis.

4-2. Future plans

We have a plan to modify satellite data selection system which consider the observation data density etc. of the neighborhood (we should introduce remote satellite data preferentially).

We need more observation data which can cover observation missing area especially ocean and high latitude area.

Simultaneous use of multiple satellite observation data can be considered as one of the solutions. Our bias correction method provides a way to treat multiple satellites data consistently.

We have a plan to upgrade horizontal resolutions (transport model and region division number) of our inversion system.

We have a plan to introduce bias corrected satellite data in our data assimilation system (LETKF).

4-3. Acknowledgement

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We thank the NOAA/ESRL and other institutions for making their observation data available to us.
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Thank you very much for your attention!