Lessons and Learned from GOSAT towards GOSAT-2

H. SUTO
A. Kuze, K. Shiomi and M. Nakajima
JAXA

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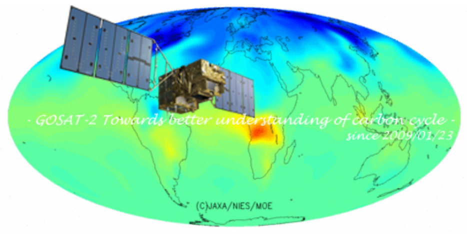
@ Yokohama, JAPAN



FACTS

GOSAT can:

1. *Distribute X_{CO2} with errors less than 1% (3-4ppm), almost 0.5%(2ppm)*
2. *Leading space-based CO_2 observation*

Group	Version	Number of Averaged TCCON site	X_{CO2}		X_{CH4}	
			Bias [ppm]	STD [ppm]	Bias [ppb]	STD [ppb]
NIES-FP	1.x	11	-8.85	4.75	-20.4	18.9
NIES-FP	2.x	11	-1.48	2.1	-6	12.5
NIES-PPDF-DOAS	-	11	0.07	2.48	-	-
ACOS	B2.9	10	0.13	2.0	-	-
RemoTeC	2.1	12	0.63	2.05	4.0	14
Univ. of Leicester	3.0 for X_{CO2} 3.2 for X_{CH4}	7	-0.2	2.3	3.4	17

NIES-FP : Y.Yoshida, et al, 2013
NIES-PPDF-DOAS: S. Oshchepkov, et al,2012, 2013
ACOS : D. Crisp, et al, 2012
RemoTeC : A. Butz, et al, 2011, G. Sandrine et al, 2013
Univ. Leicester : H. Boesch, 2012

Retrieved scan rate for NIES, ACOS and RemoTeC

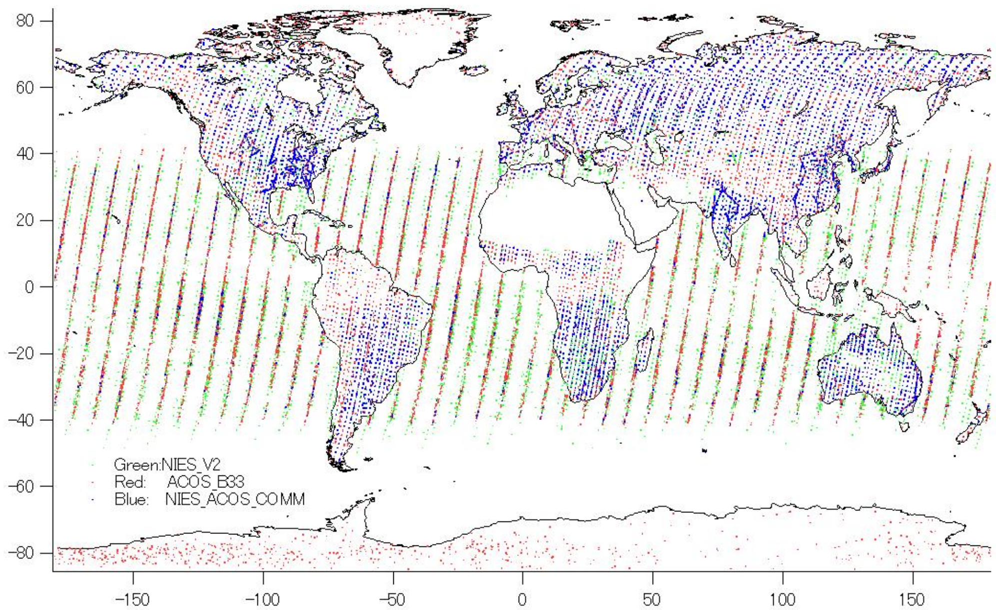
Gain	TOTAL Obs.	Retrieved Scans							
		NIES v1 GU	NIES v2 GU	ACOS B2.9		ACOS B3.3		RemoTeC V2.1	
				w/ QF	wo/ QF	w/QF	wo/ QF	w/ QF	wo/ QF
H	3865612	32836 <0.0084> (1)	63699 <0.0165> (1.94)	170901 <0.0442> (5.20)	583757 <0.1510> (17.78)	74423 <0.0193> (2.27)	421801 <0.1091> (12.85)	38391 <0.0099> (1.17)	214460 <0.0555> (6.53)
M	169663	31854 <0.1877> (1)	21338 <0.1258> (0.67)	23333 <0.1375> (0.73)	77222 <0.4551> (2.42)	5440 <0.032> (0.17)	73470 <0.4330> (2.306)	11868 <0.0670> (0.37)	55000 <0.3242> (1.73)

Values in parentheses are derived against NIES v1
Values in brackets are derived against Total obs. (OB1D & SPOD) during 2009/06/03 to 2010/07/31

Quality Filter (QF)
ACOS: Master Quality = GOOD
NIES: GU
RemoTeC: FLAG_QUAL=GOOD, GOOD_MGAIN, GOOD_GLINT

Courtesy ACOS and A.Butz

Survived scan rate during 2009/06/03 – 2010/07/31 Gain H



NIES:ZPD time
RemoTeC: ZPD time
ACOS: TAD time

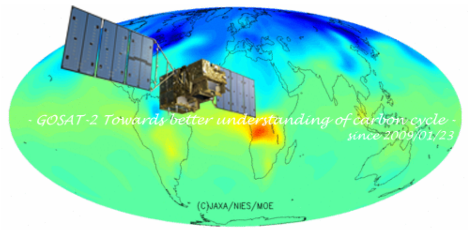
	NIES V02.xx	RemoTeC V2.1	ACOS B3.3	ACOS B29	NIES & RemoTeC	NIES & ACOS_B3.3	NIES & ACOS B2.9	ACOS B3.3 & RemoTeC V2.1	NIES & RemoTeC & ACOS B3.3
Exposure Count (H)	63,699	38,391	74,423	170,901	15,978	27,106	45,137	15,887	8,812
Comments	2009/6/3 — 2010/7/31	2009/6/3 — 2010/7/31	2009/6/3 — 2010/7/31	2009/6/3 — 2010/7/31	Remo/NIES 0.25	ACOS/NIES 0.43	ACOS/NIES 0.71	Remo/ACOS 0.21	All/NIES 0.14

Matching condition

NIES _Obs_Time - 0.5(s) < ACOS_Obs_Time + 2(s) < NIES _Obs_Time + 0.5(s)

Lessons and Learned on Instrument

No	Items	Effects	Counter action on GOSAT	Counter action on GOSAT-2
1	Micro-vibration	Spectral distortion	Correction on L1	Match the delay value between laser and IR signal
2	Laser misalignment	Wavenumber shift	-	Apply the monolithic mirror (improve robustness)
3	ZPD position shift	Changing spectral resolution	Reset operation	Improve the electronic design
4	Pointing offset	Geo-location error	Correction	Change the mechanical design
5	Non-linearity on LPF circuit	Spectral distortion	Correction on L1 & L2	Improve an analogue circuit
6	Non-linearity on ADC	Spectral distortion	-	Apply DC sampling or change the type of ADC
7	Non-linearity on Pre-amp	Spectral distortion	-	Improve an analogue circuit



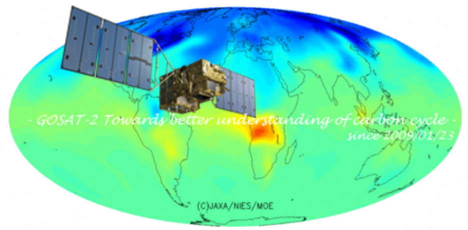
Overview of User's Requirements - Brief summary of GOSAT WS -

1. Improve the aerosol detectability for precise X_{CO2} and X_{CH4} measurement (reduce bias errors)

2. Increase the precision and accuracy of single shot "Flying TCCON"

3. Extend or shift the band coverage of Band1, to precise retrieval of Fluorescence

4. Extend the sun-glint observation range



Science Requirements

1. *Maintain the global and continuous observation from space*

2. *Keep or increase the spectra quality (lessons learned from GOSAT)*

3. *Improve understanding of natural source/sink*

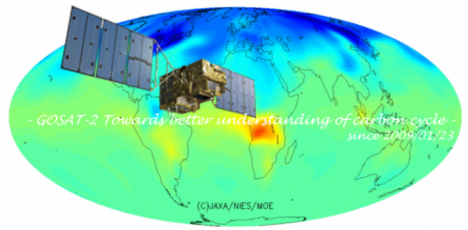
4. *Reduce bias and variation coupled with Aerosol information*

5. *Increase the number of good quality observation data*

6. *Measure CO*

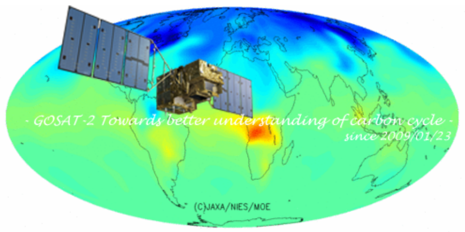
Baseline of instrumental requirements

1. SNR> 300 (all bands), Resolution < 0.2 cm-1, optimize the spectral coverage for each bands.
2. High precise aerosol observation
3. Increasing the number of good quality observation
4. Increasing the number of clear sky observation
5. CO and Fluorescence measurement
6. Increase the robustness and reduce the risks and cost for technical points of view.

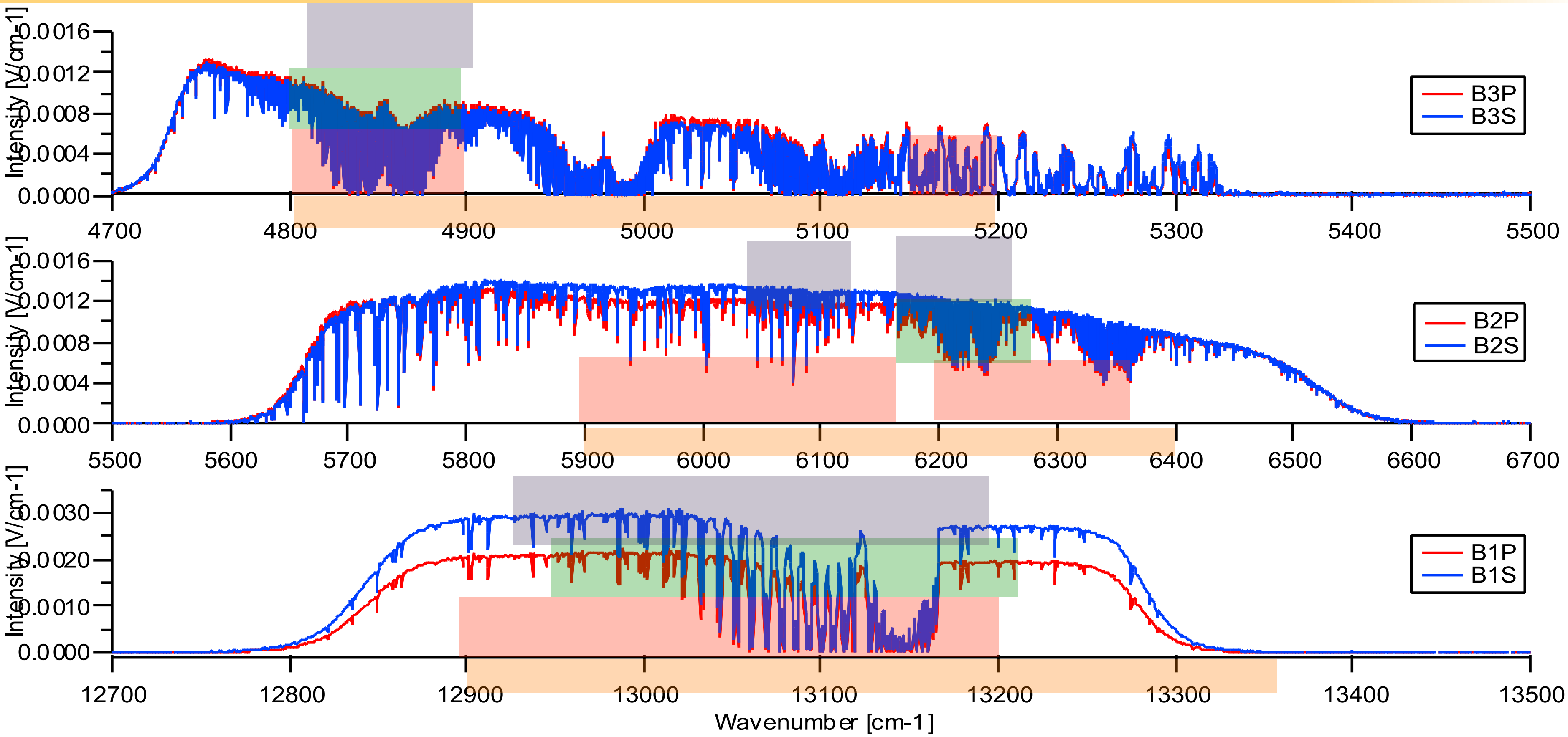


Preliminary concept of modification

Requirements	Technical points	Actions
①SNR	Reducing the noise	Optimize the spectral coverage Improve analog electronics
	Increasing the signal	High modulation efficiency
②Aerosol measurement	CAI-Band1 Spectrometer Improved observation	Imaging spectrometer Multi-angle measurement
③Increasing the number of good quality observation	Increase sun-glint rage	Optimize pointing range
	Self pointing control to direct the informative location	Intelligent sampling
④Increasing the clear sky observation	Self pointing control to direct clear sky footprint	Intelligent pointing
⑤CO and Fluorescence measurement	CO Band Optimize the fluorescence band	Add 2.3 micron band Shift the spectral coverage of O_2A



Optimization of Spectral Coverage



NIES

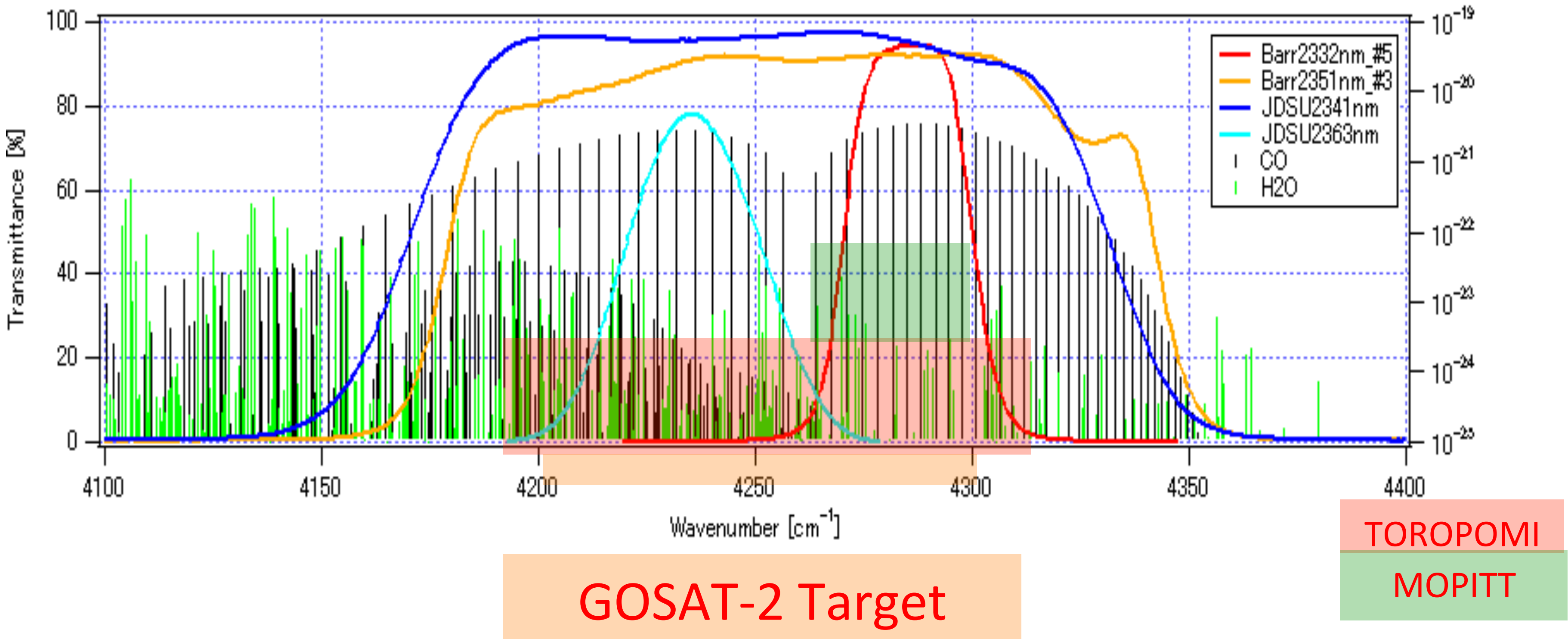
ACOS

RemoTec

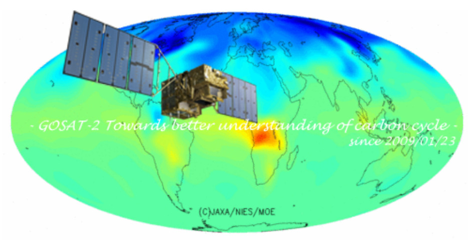
GOSAT-2 Target

2013/05/29

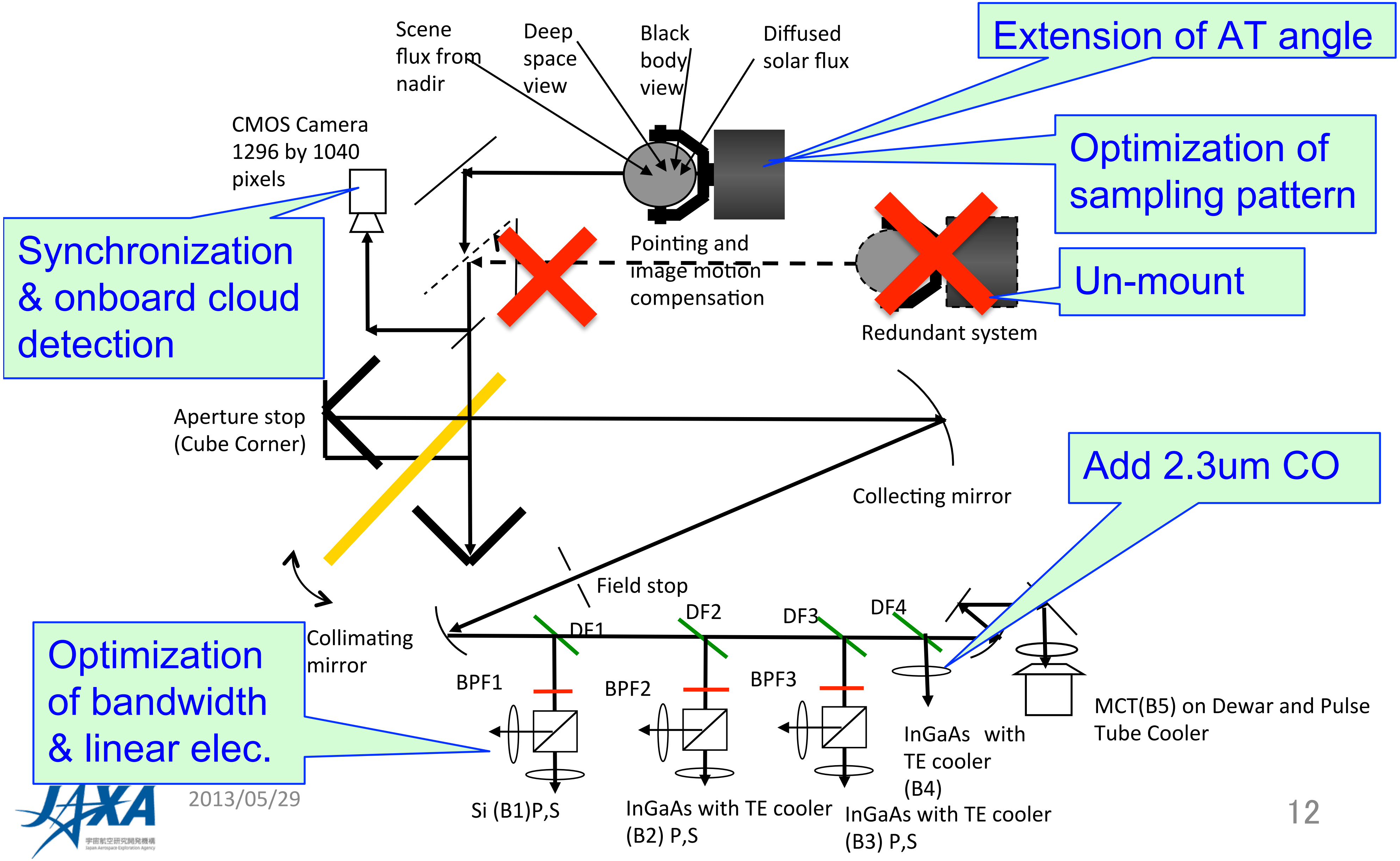
Optimization of CO bandwidth



- We demonstrated wide and narrow band path optical filters.
- In hardware point of view, narrow band is suitable to get higher SNR.

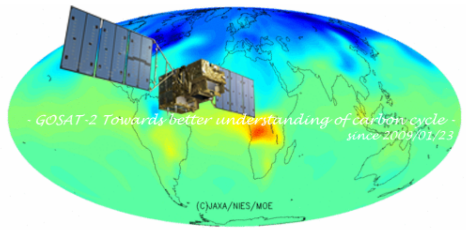


Modification plan for FTS

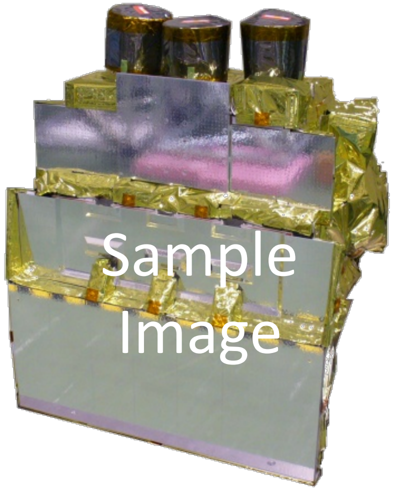


Preliminary Specification of FTS

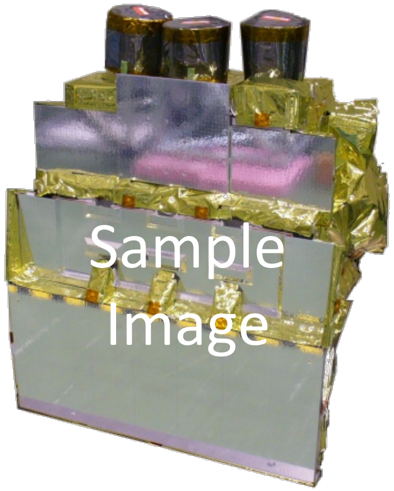
Items		Specification				
Orbit	Altitude	666km				
	Revisit cycle	3 days, 14+2/3 orbit per day				
Pointing-Mechanism	Coverage	Cross Track (+/- 35 deg.), Along Track (+/- 40deg)				
	Sampling & pointing	About 160 km interval Intelligent sampling and pointing by the target mode (optimized 56,000 points)				
IFOV	10.5km with imaging capability					
FTS-Mechanism	Band	1 (P/S)	2 (P/S)	3(P/S)	4	5
	Coverage (cm^{-1})	12900 -13350	5900 - 6350	4800 - 5200	4200 - 4300	650 - 1400
	Target	O_2A Chlorophyll Fluorescence	CO_2,CH_4	CO_2	CO	CO_2, CH_4, O_3
	Sampling duration	4 sec				
	Resolution	0.2 cm^{-1}				
	SNR Target	400 (for B1), 300 (for B2,3,4) albedo 0.3, SZA=30deg.				



Preliminarily specification of Upgraded Cloud and Aerosol Imager



CAI-Forward-Looking

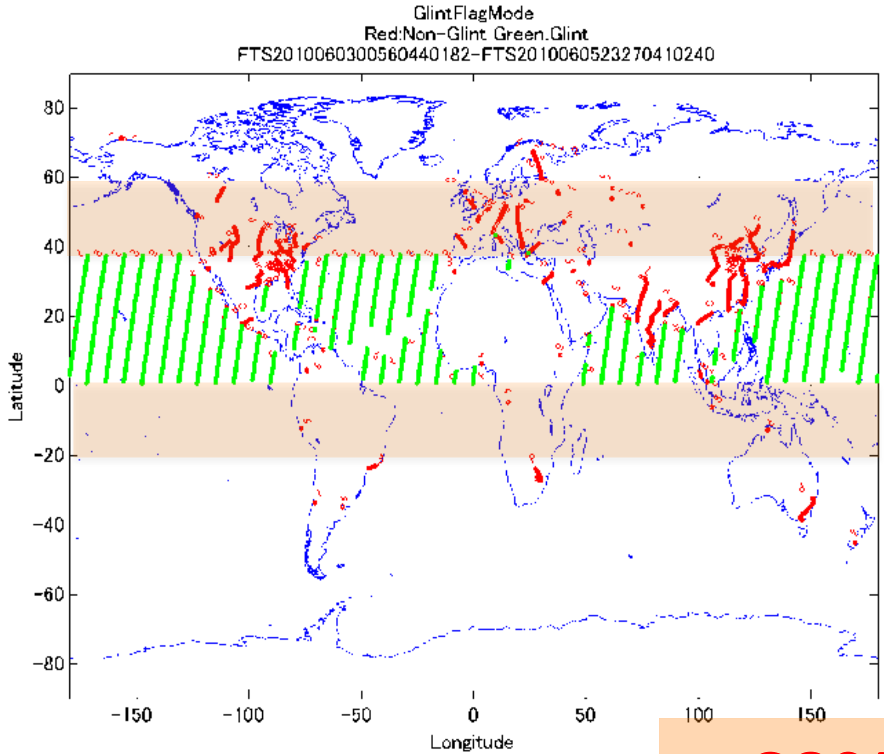


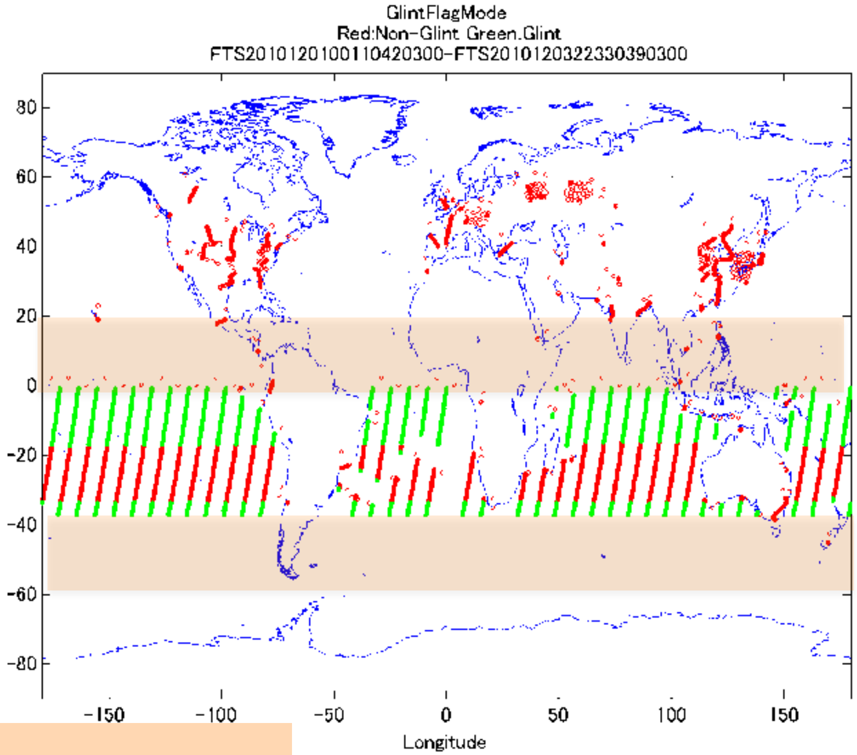
CAI-Backward-Looking

Band	Center Wavelength [um]	Band Width [nm]	IFOV [km]	No.of Pixels (Cross Track)	Swath [km]	Tilt angle [deg.]
1*	0.340	20	0.5	2000	1000	+20
2*	0.430	20	0.5	2000	1000	+20
3	0.870	20	0.5	2000	1000	+20
4	1.60	90	1	500	500	+20
5	0.380	20	0.5	2000	1000	-20
6*	0.55	20	0.5	2000	1000	-20
7	0.87	20	0.5	2000	1000	-20
8	1.6	90	1	500	500	-20

※additional bands (tentative)

Extend Sun-glint coverage





GOSAT-2 Target

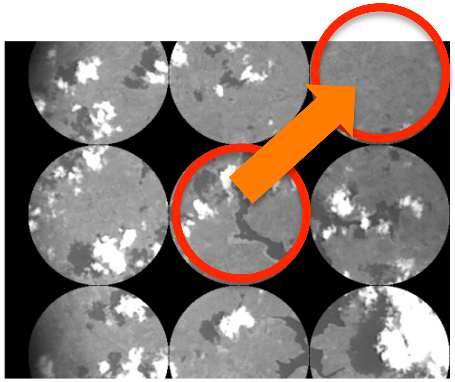
- The current limit of sun-glint coverage is related with AT angle capability (+/-20deg =~ 40deg of latitude).
- The target is extending +/-40 deg. of AT angle travel by improved pointing mechanism.

Concept of Intelligent pointing

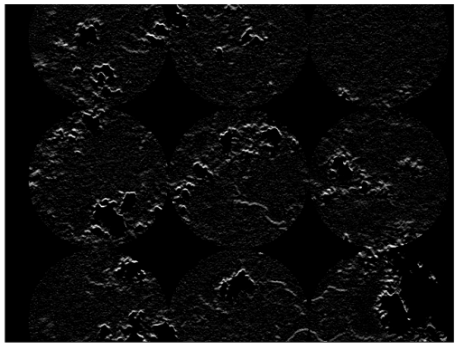
Use onboard camera data

Within turnaround duration,

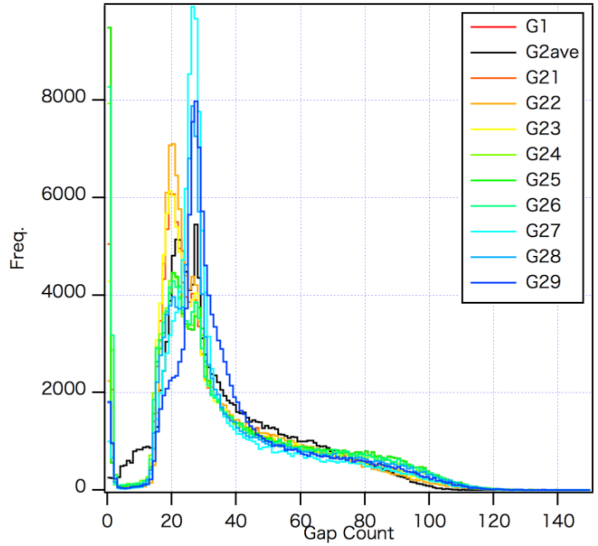
1. Take a picture (ex: 9 candidate IFOV by 1 shot)
2. Calculate the contrast and determine the clear pixel
   It is appeared the high contrast between the contaminated pixel and non-contaminated pixel.
3. change the PM position



Candidate IFOV

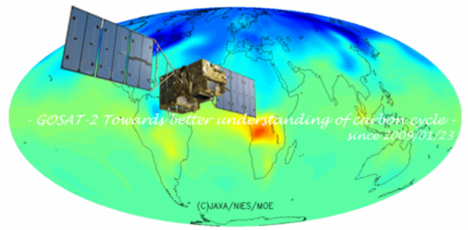


Contrast of pixel by pixel
Or compare the radiance level



Histogram of count of contrast (to determine the criteria)

At least 2 times higher than that of non-intelligent pointing



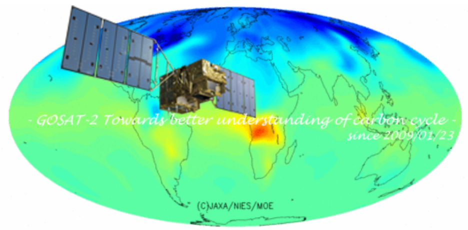
Summary

1. Improve FTS & CAI with small design modification

2. CO and aerosol measurement capability

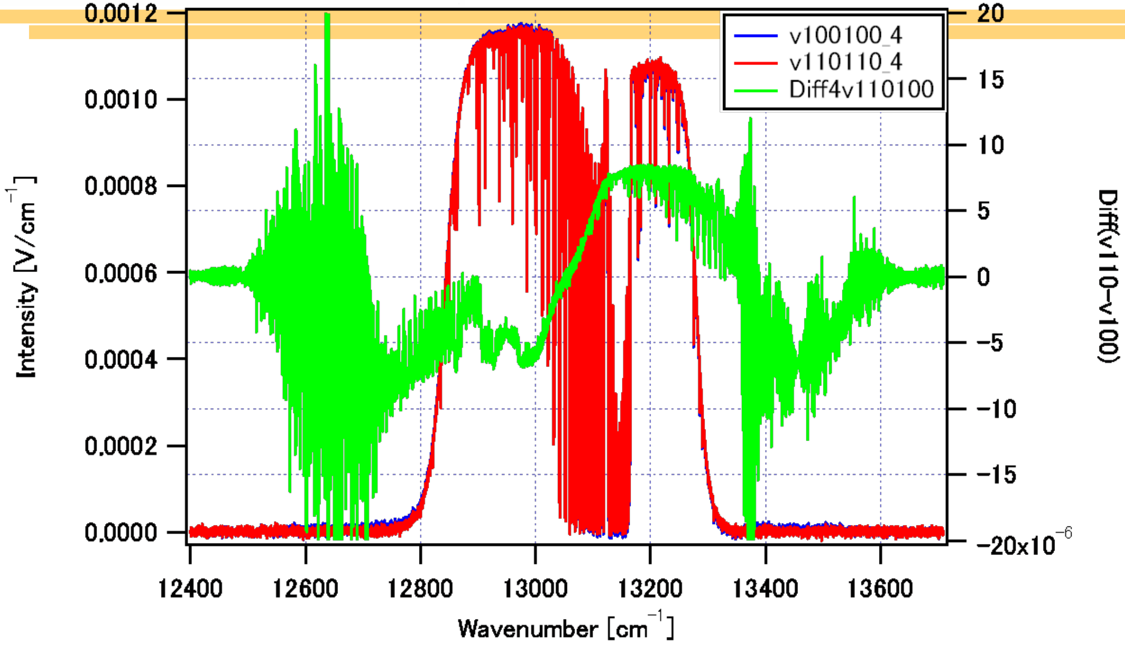
3. New function: intelligent pointing and sampling

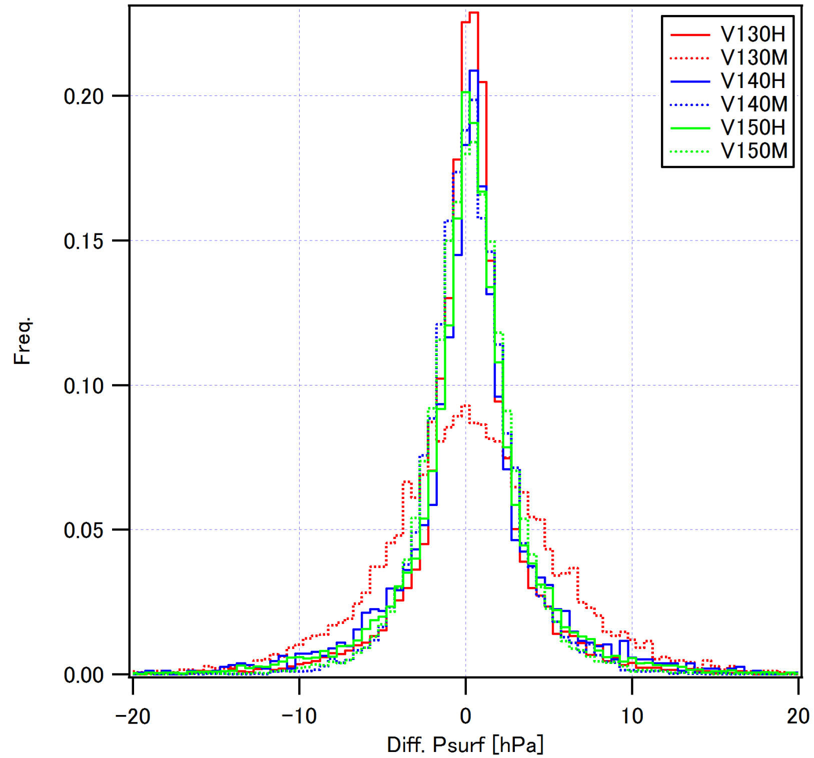
4. Launch target: the beginning of 2018



Backup slides

Scan-Fluctuation Correction





$$T_{ZC\_Meas} = t_{fringe} \cdot n + \sum_{i=1}^{2} \{ T_{Delay} \cdot (1 + A_i \cos(2\pi f_i t + \phi_i)) \}$$

where $n : 1, 2, \cdots N_{Total\_fringe}$

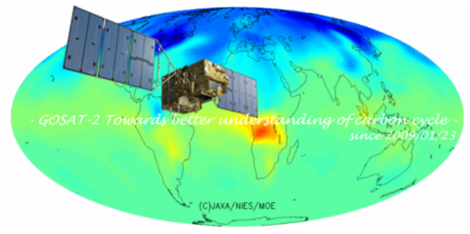
T_{Delay} : *Delay Time*

f_i : *Frequency of perturbation*

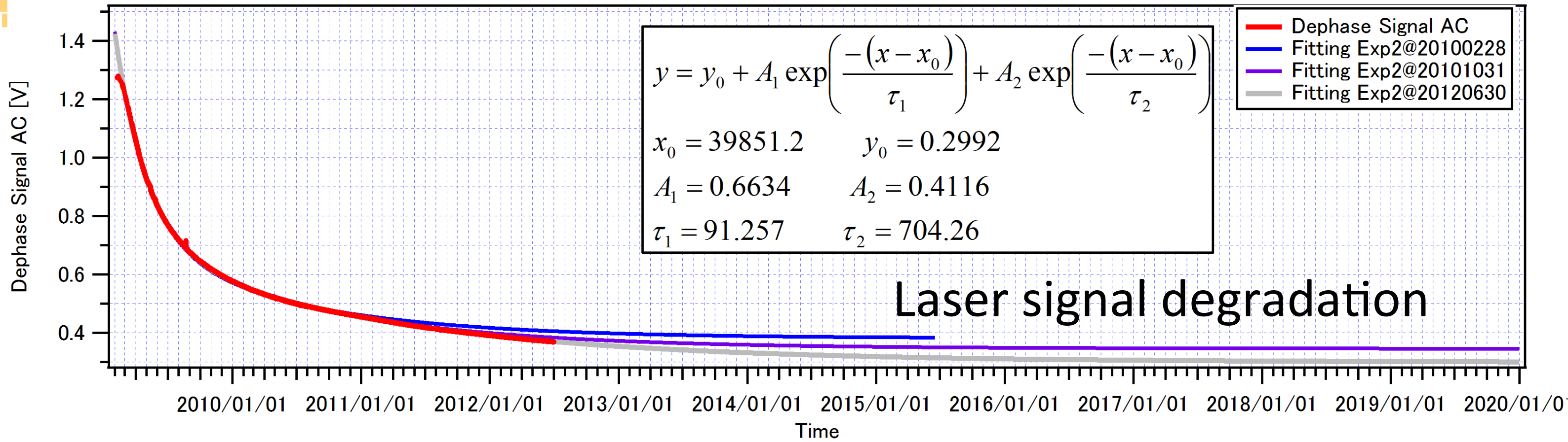
A_i : *Amplitude of perturbation*

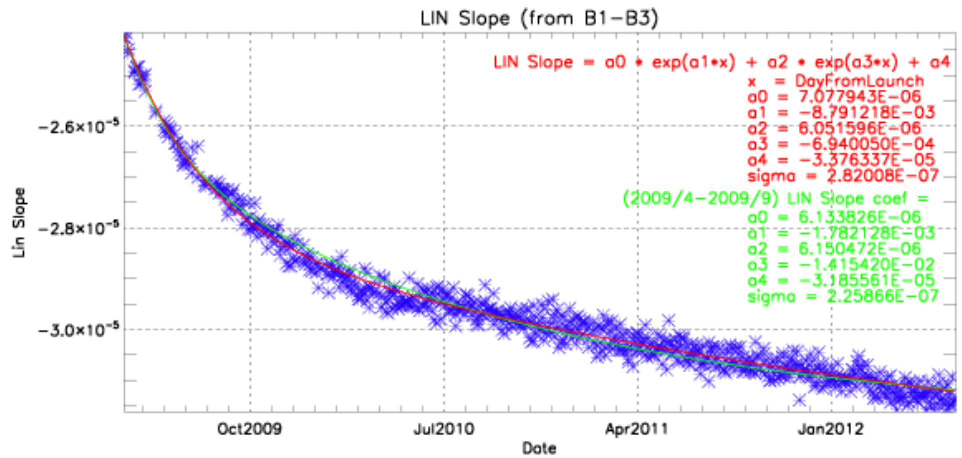
ϕ_i : *phase of perturbation*

H.Suto, prepared.

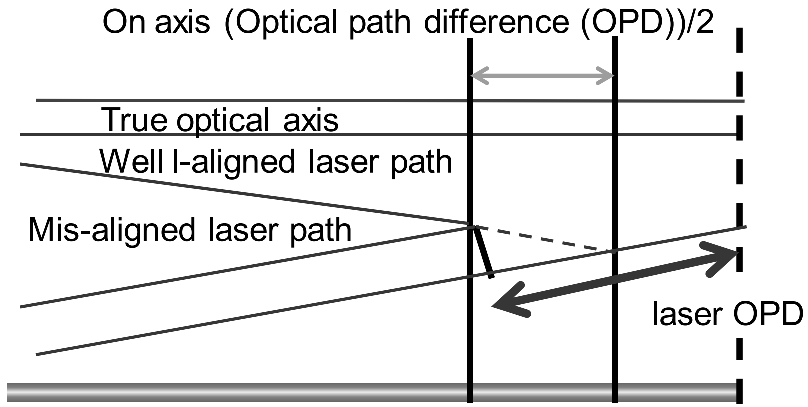


Metrology laser misalignment

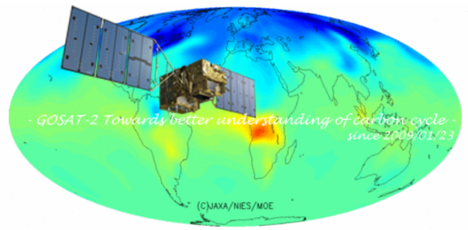




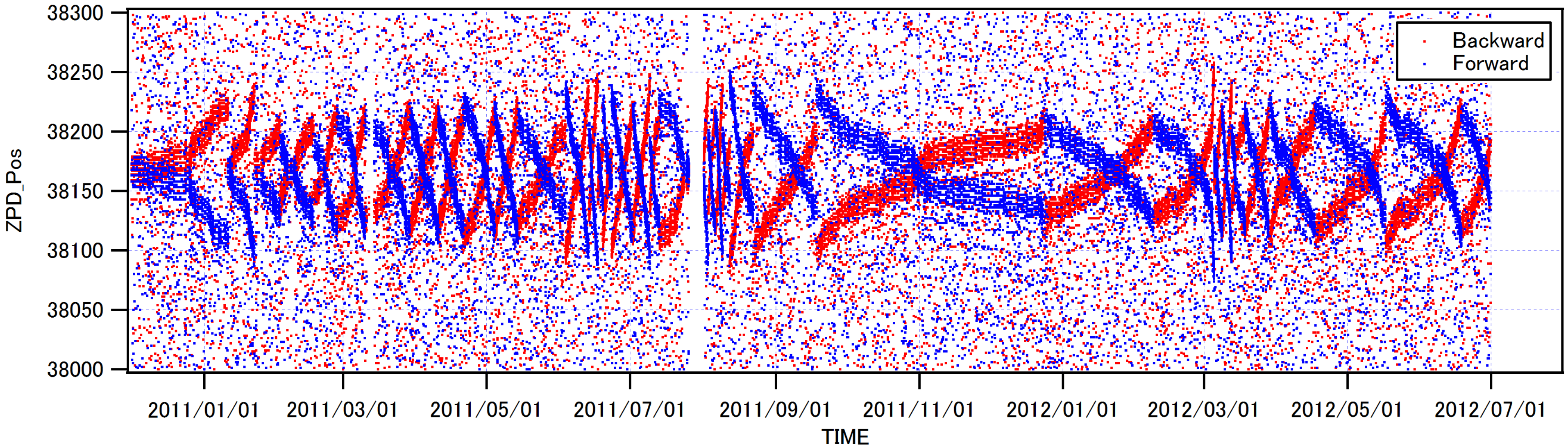
Wavenumber shift



Laser signal degradation caused by misalignment of metrology laser channel



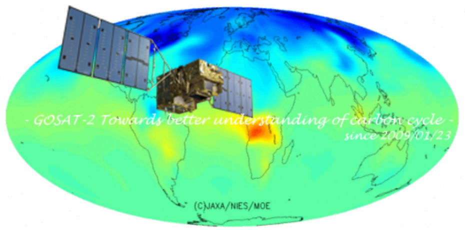
ZPD position shift



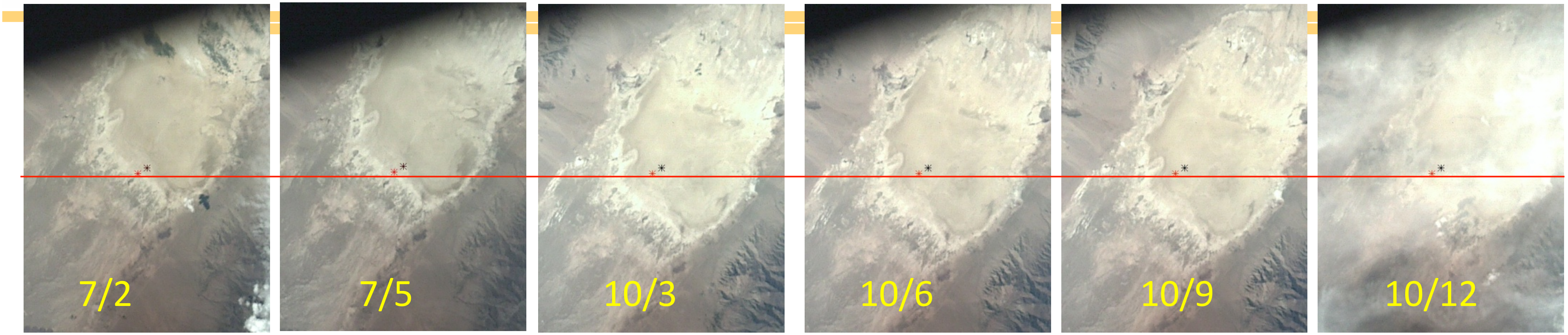
The root-cause of ZPD shift are

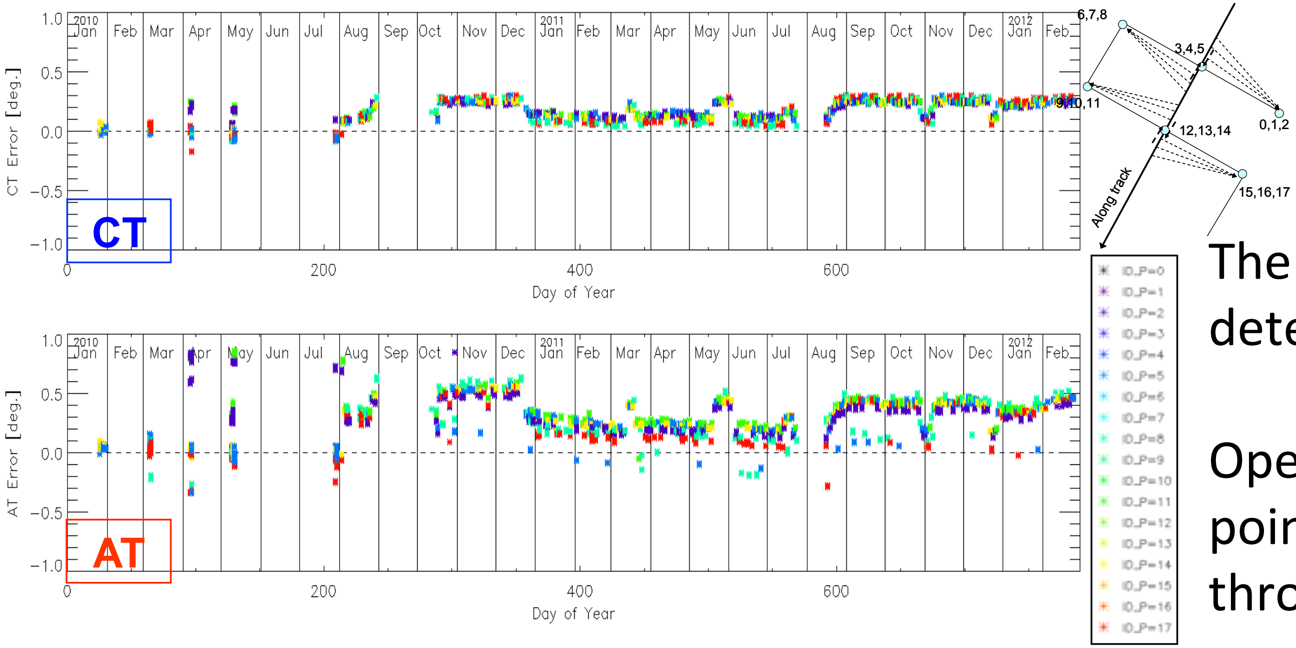
1. electromagnetic noise on fringe/dephase detection, >> electronic design
2. High path filter on turn-around, >> electronic design
3. Vibration from pointing motion. >> mechanical design

Counteraction current instruments: operational reset by command.



Pointing Error



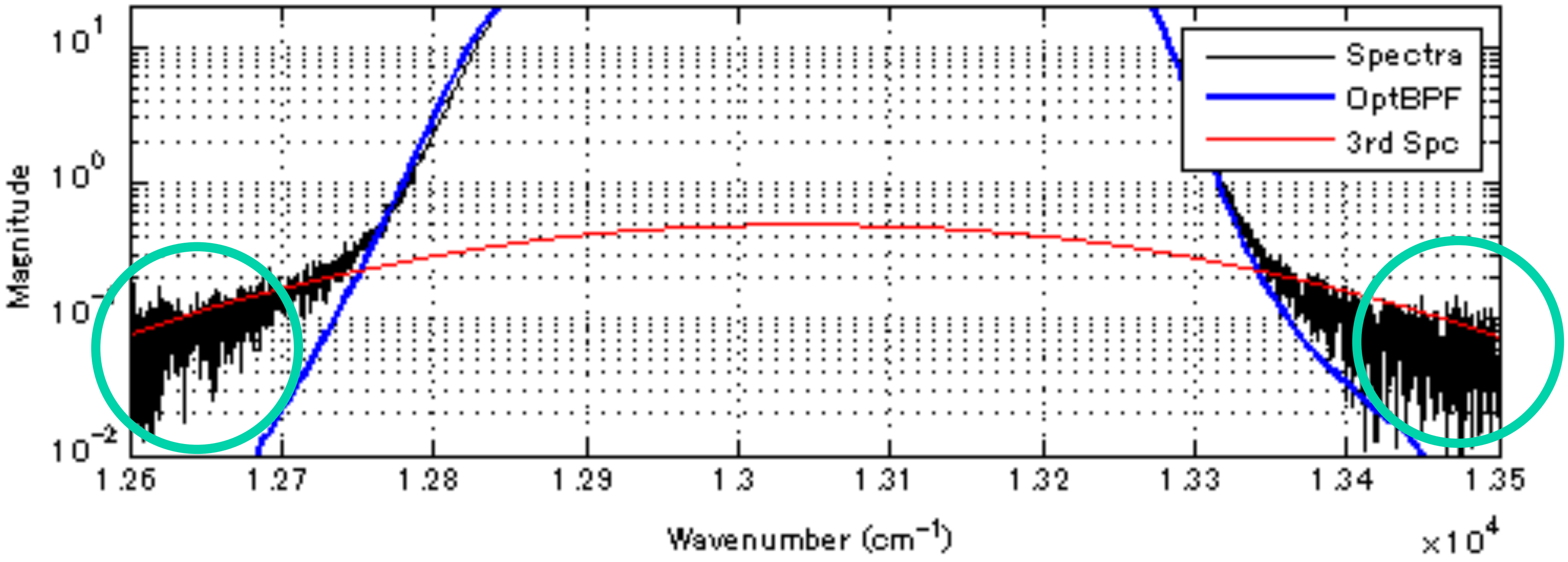


The root cause is not determined yet.

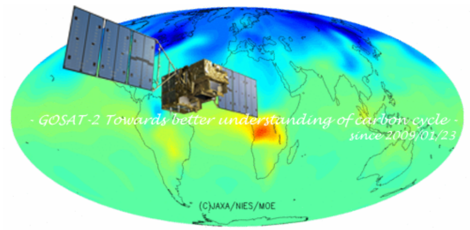
Operationally, the knowledge of pointing offset will provided through the webpage.

2013/05/29

Non-linearity on analogue circuit

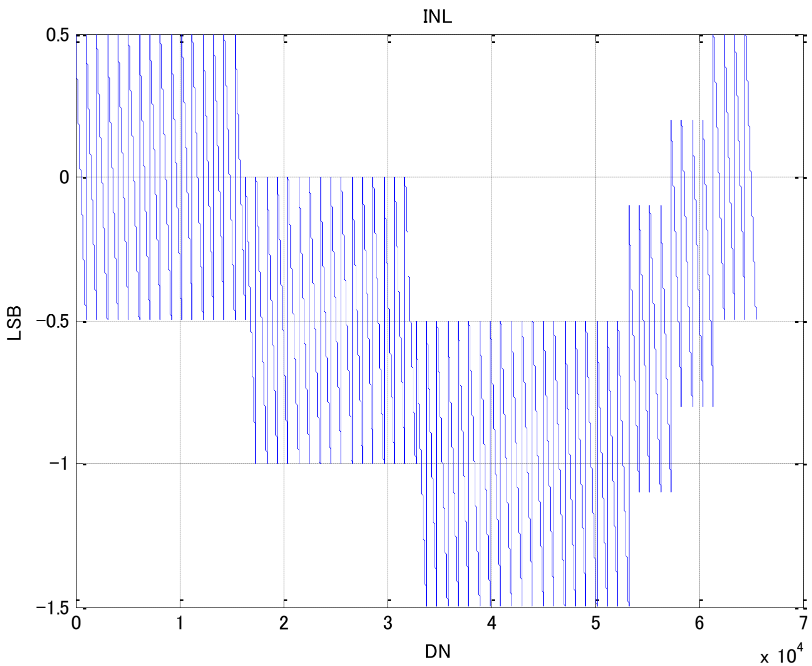


- Low path filter on Band1 circuit create artificial signal both of in- and out-of-band.
- These artifacts leads systematic bias on the retrieved O_2 products.
- Empirically, the correction parameters were determined and applied on the recent L1B products.

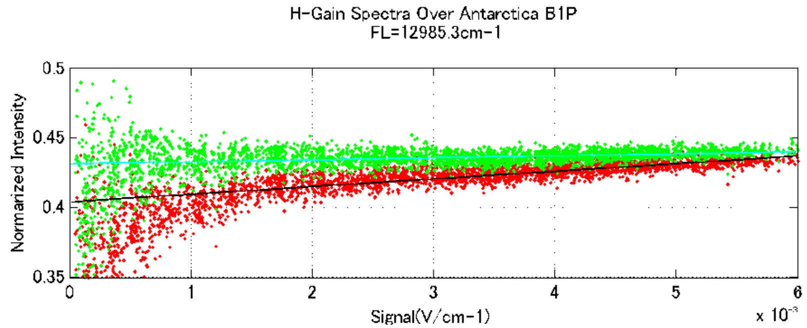


Non-linearity on ADC

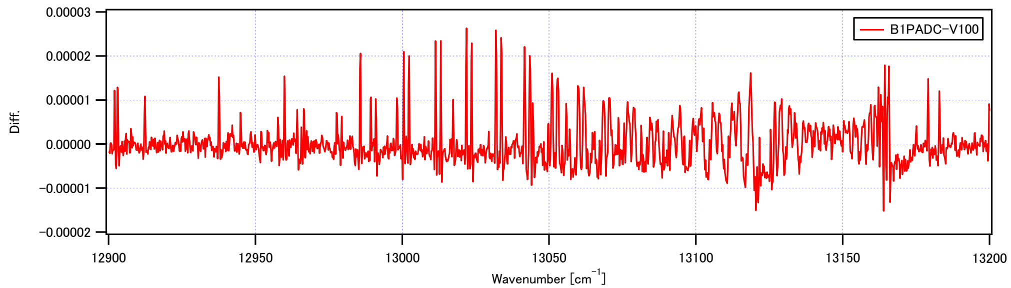
- Motivation; Fraunhofer depth is depended on input radiance over Antarctica. (Ideally, the depth of Fraunhofer lines are independent of input radiance.)
  - ADC character is highly affect the non-linearity of band1 data.
  - Unfortunately, the correction scheme is still underdeveloping phase.



ADC Non-linearity correction model



Fraunhofer liens depth against input radiance



ADC effects on spectra