Development of alternative-band algorithms for ADEOS-2 GLI ocean color products

*H. Murakami*1, W. Chen*1, Y. Park*1,*

*Y. Mitomi*2, S. Kawamoto*2, M. Yoshida*2,*

*W. Takahashi*3, and I. Asanuma*1*

**1: NASDA /EORC, *2: RESTEC, *3: JNUS*

GLI ocean bands assumed to be saturated

Channel No.	*Wavelength [nm]*	*Maximum radiance Spec. high/low gain [W/m²/str/µm]*	*Maximum radiance PFM high/low gain [W/m²/str/µm]*	*Ratio of Saturation area [%] estimated by OCTS*	*Used bands in Standard Alg.s*				
					OTSK1a Atmos. corr	*OTSK2 CHLA*	*OTSK5 K490*	*OTSK6 SS*	*OTSK7 CDOM*
1	380	365	726	0					
2	400	139	172	0					
3	412	130	136	0					
4	443	109 /560	114 /718	0		*Alt*			*Ori*
5	460	108 /624	131 /813	0		*Alt*	*Alt*		
6	490	86	66	18		*Ori*	*Ori*	*Ori*	
7	520	64 /539	97 /614	0		*Alt*		*Ori*	*Ori*
8	545	56 /549	99 /634	0		*Alt*	*Alt*		
9	565	47	41	4		*Ori*	*Ori*	*Ori*	
10	625	33	37	nearly 0					
11	666	26	23	10					
12	680	24	24	10					
13	678	438	400	0	*Alt*				
14	710	18	17	--					
15	710	311	275	0	*Alt*				
16	749	14	12	33	*Ori*				
17	763	350	350	0	*Alt*				
18	865	9	8	30	*Ori*				
19	865	304	260	0	*Alt*				
24	1050	203	240	0	*Alt*				
26	1240	138	205	0	*Alt*				

Personnel

EORC team

Murakami (work coordination, data analysis)

Takahashi (model simulation and analysis)

Mitomi and RESTEC (data analysis)

Chen (data analysis, implementation)

Park (data analysis, in-water)

Asanuma (adviser)

information

PIs

Ishizaka,

Kishino,

Mitchell,

Fukushima,

Frouin

Modify operational codes

Can we use land gain bands, CH13 (678nm), CH19 (865nm), CH26(1240nm)?

- Study using numerical simulated data
  - Study of aerosol selection schemes
  - Study of noise levels
- Study using MODIS Level 1B data
  - Noise level
  - Study of switching schemes
  - Study of noise reduction schemes
  - Study of negative nLw problem

Evaluation of algorithm error and noise caused by alternative bands using numerical model

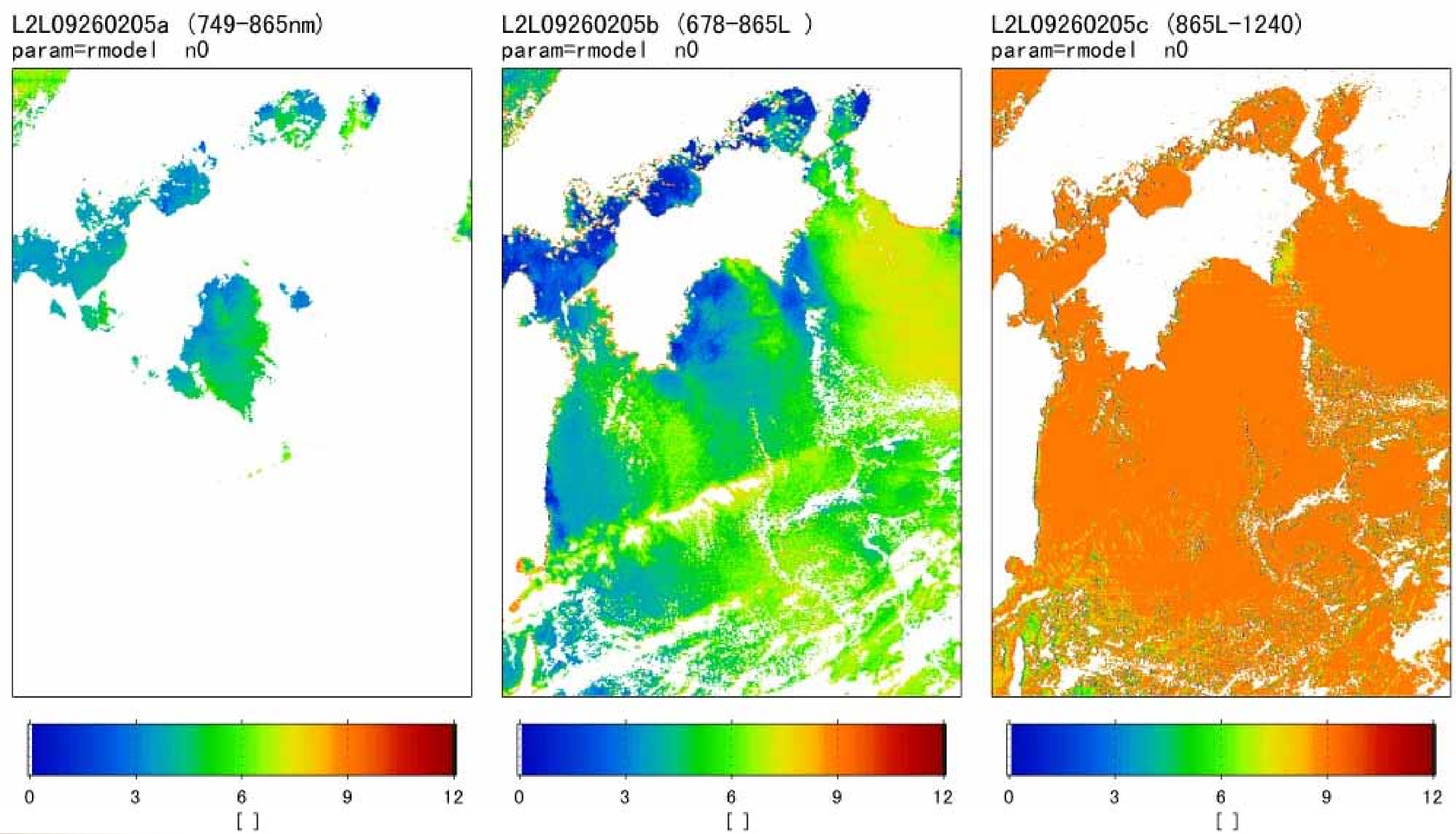
Bias and Standard Deviation of each nLw

Atmos. corr. band	*CH16-18*		*CH13-19*		*CH19-24*		*CH19-26*	
nLw band	*Bias*	*SD*	*Bias*	*SD*	*Bias*	*SD*	*Bias*	*SD*
nLw 443	0.0432	0.0170	0.1720	0.0479	0.1920	0.215	0.477	0.0621
nLw 460	0.0383	0.0167	0.1630	0.0473	0.1820	0.210	0.466	0.0628
nLw 490	–0.1070	0.0124	–0.0130	0.0353	0.0029	0.172	0.237	0.0550
nLw 520	–0.0466	0.0107	0.0232	0.0282	0.0362	0.140	0.226	0.0475
nLw 545	–0.0565	0.0097	–0.0005	0.0243	0.0111	0.125	0.181	0.0450
nLw 565	–0.0338	0.0071	0.0115	0.0201	0.0217	0.110	0.171	0.0398

Unit [$mW/cm^2/str/\mu m$]

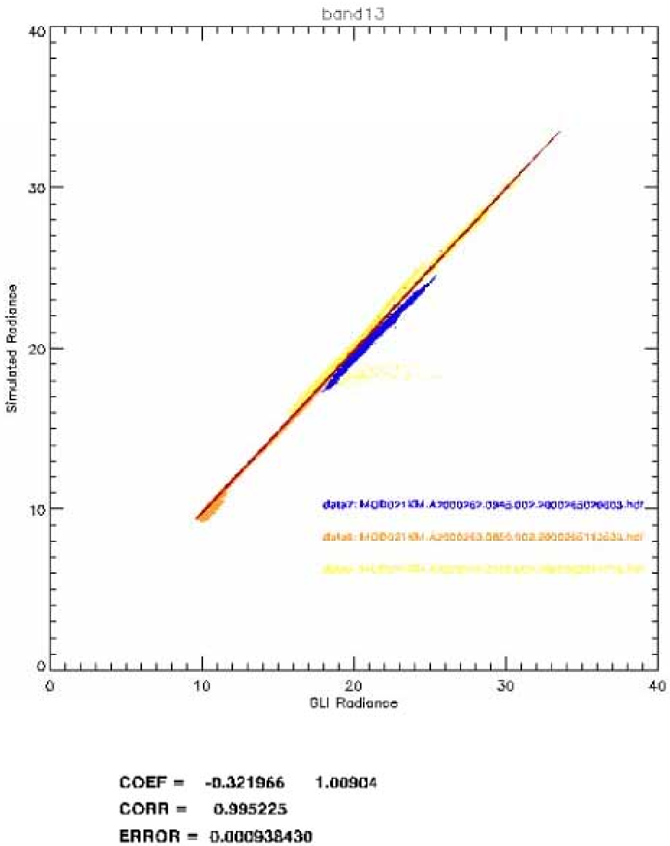
Test by MODIS Level 1B data

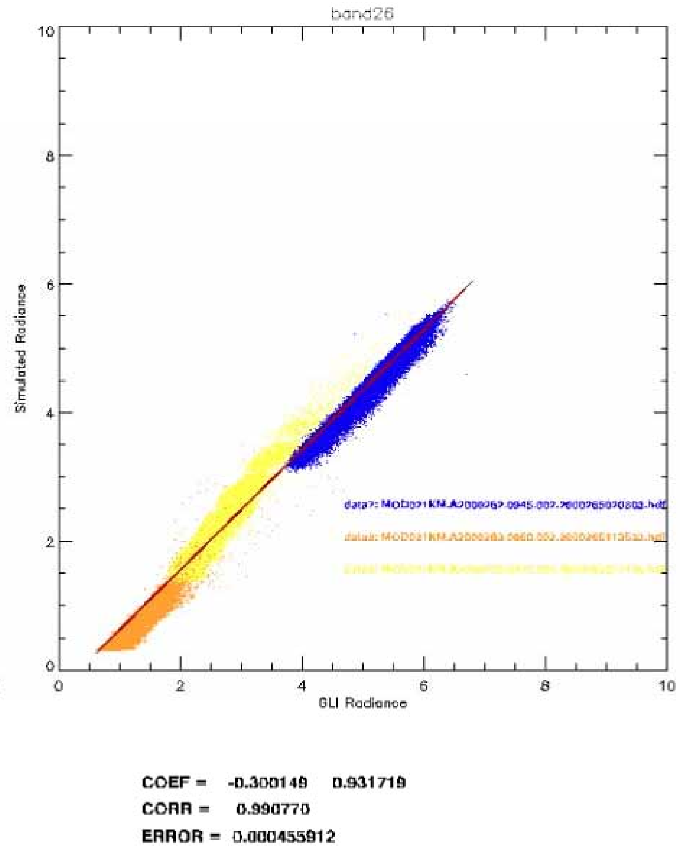
Large difference is appear maybe due to calibration characteristics of MODIS L1B



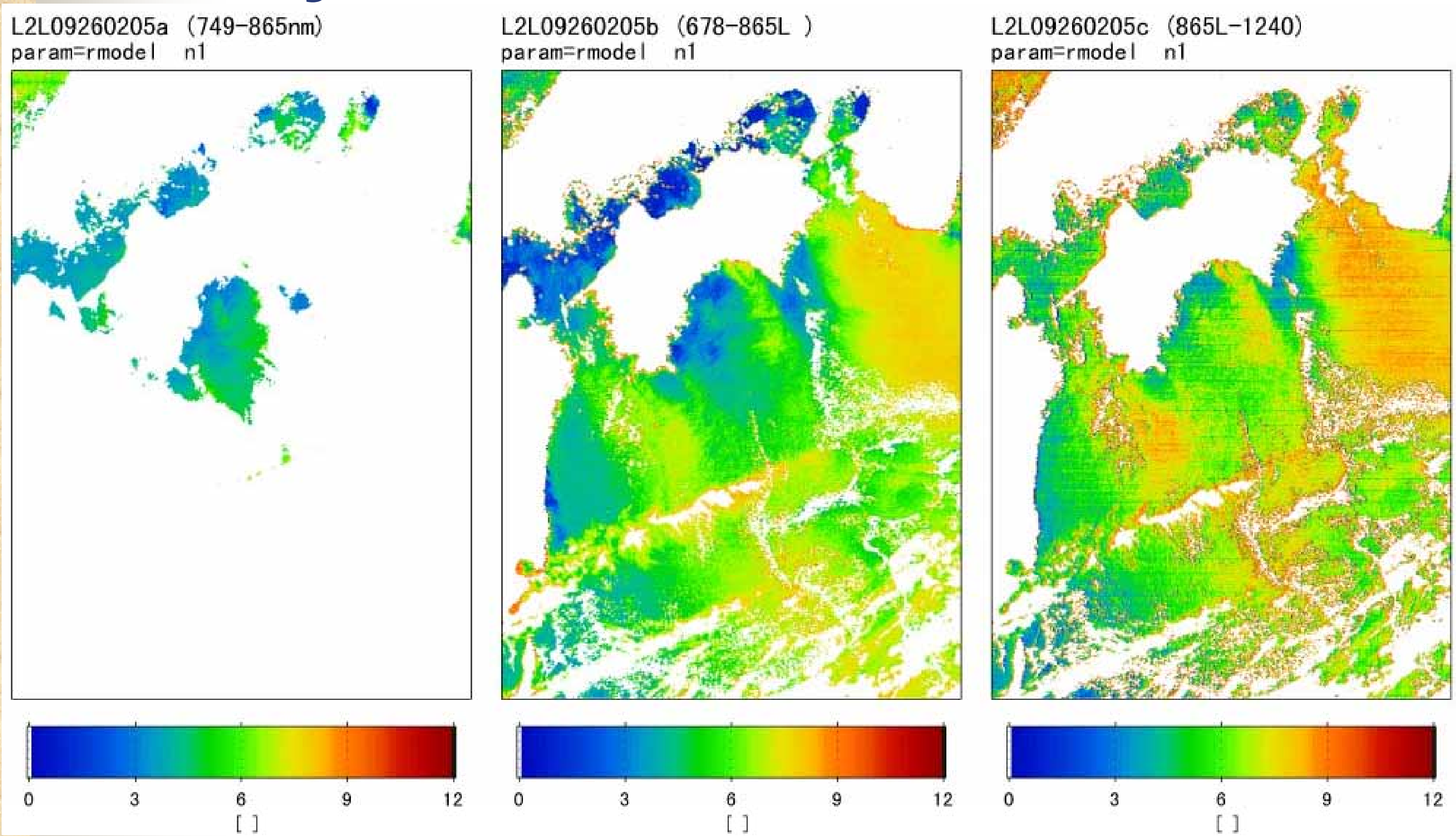
Adjustment by aerosol models selected by OTSK1a

We corrected the alternative near infrared (NIR) radiance to select same aerosol models with ones by the original NIR bands. The same procedures will be need in the real GLI operation after launch.

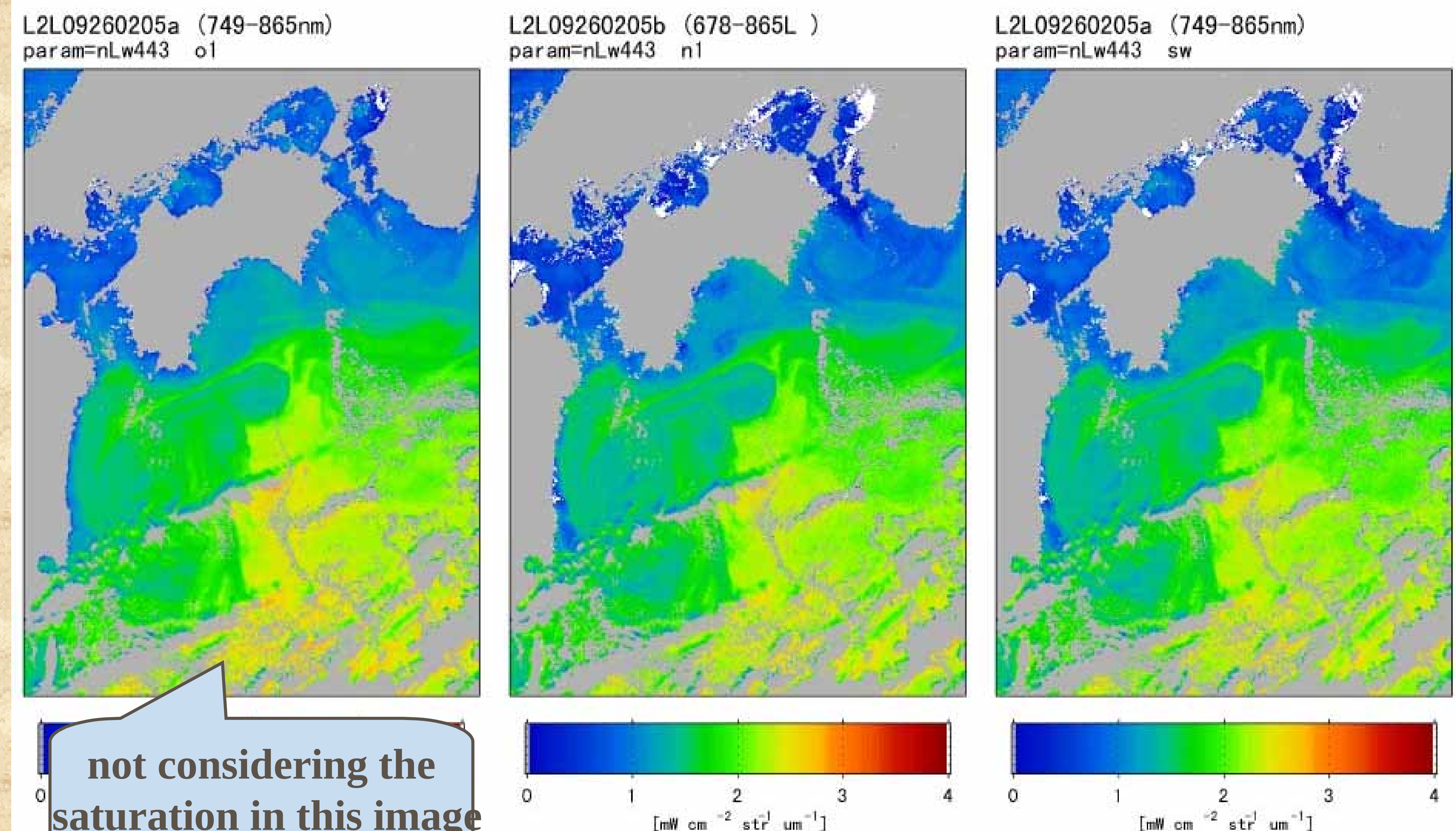




Results of aerosol selection after the NIR adjustment

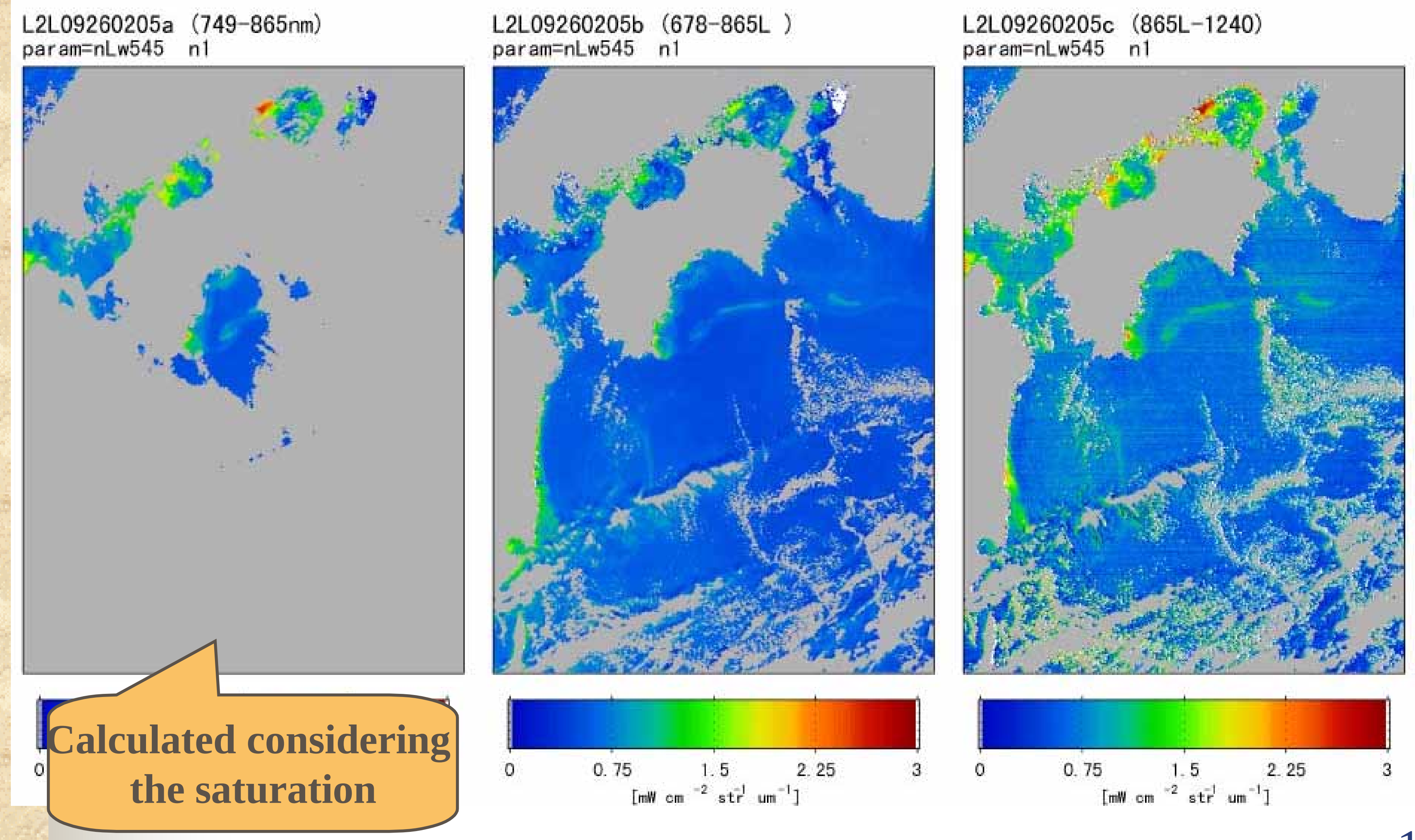


nLw 443nm
by CH16-18, CH13-19 and CH19-26

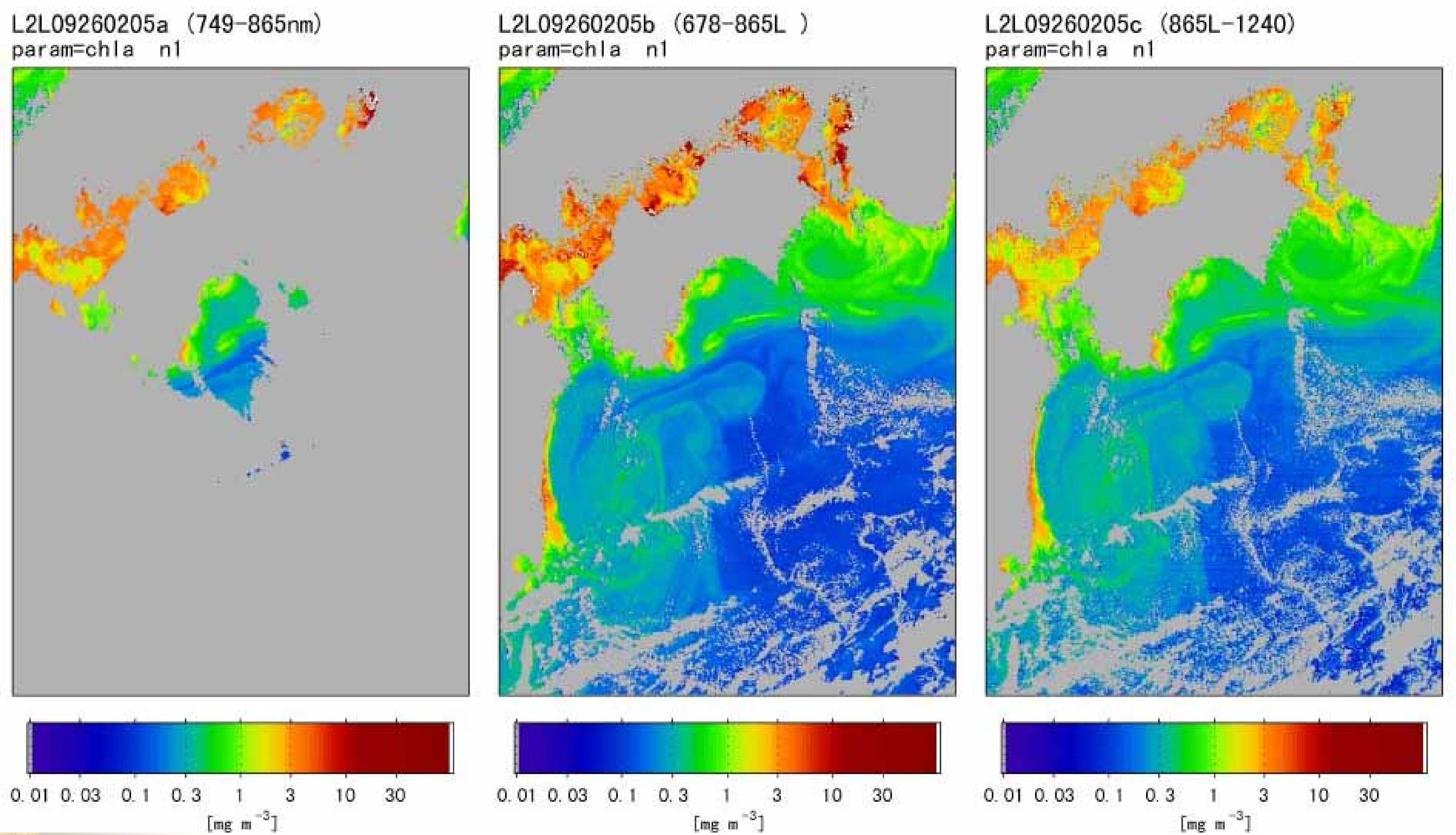


not considering the saturation in this image

nLw 545nm
by CH16-18, CH13-19 and CH19-26



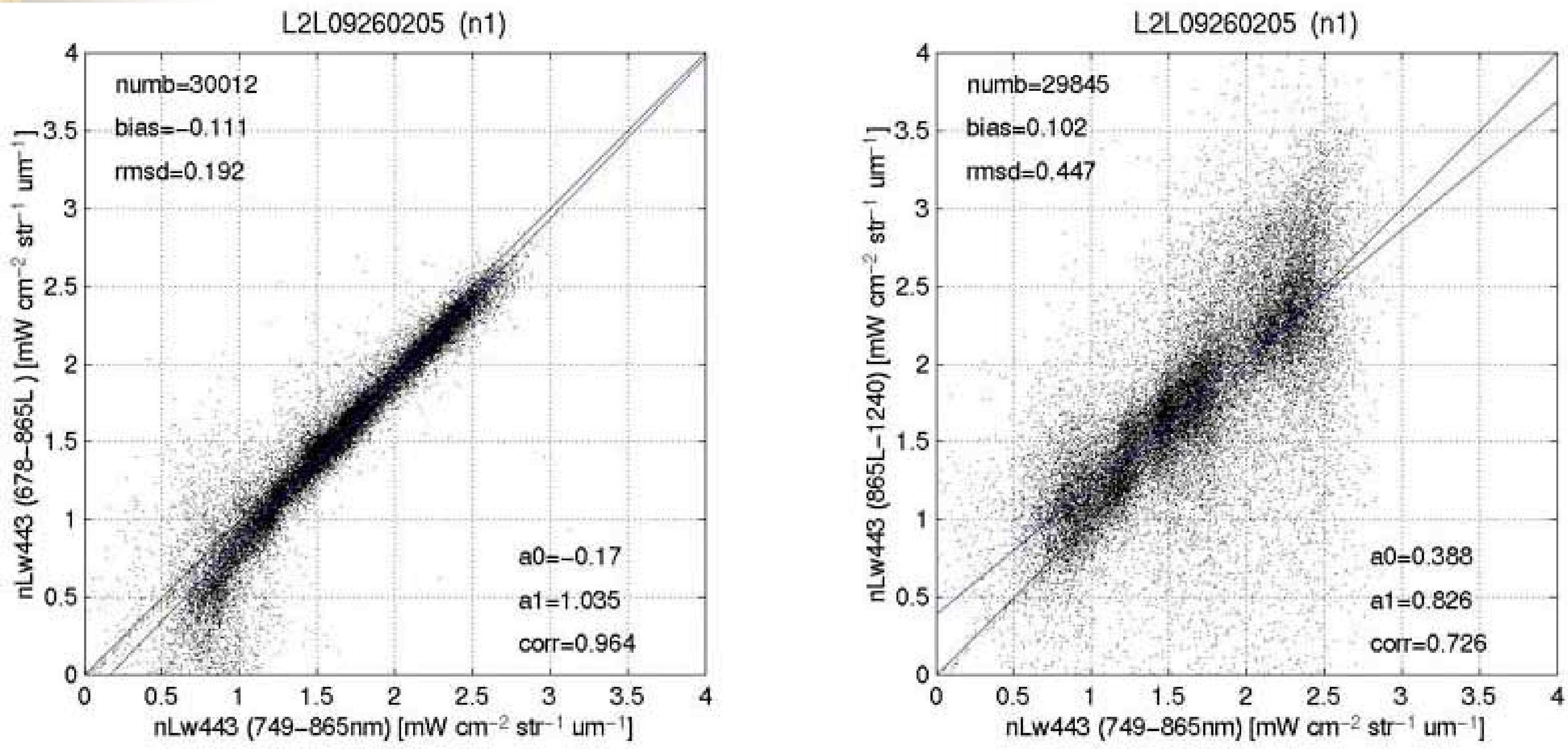
CHLA by CH16-18, CH13-19 and CH19-26



Scatter diagram of nLw443

X-axis: CH16-18

Y-axis left: CH13-19, right: CH19-26



Switching Scheme

GLI-simulated Lt from MODIS

.. ***ratio1*** *and* ***ratio2*** *calculated by Lt749 and Lt865*

.. *convert to reflectance*

.. *subtract molecular reflectance*

for models M= 1 to 9

.. calculate τ_a for aerosol-correction bands

τa(749_{CH16}), τa(678_{CH13}) , τa(865_{CH18}), τa($865'_{CH19}$)

.. *by K-extension of model M*

τa(749_{CH13}), τa(865_{CH19})

added process

.. ratio1 ***.. ratio2*** ***.. composed by ratio1 and ratio2***

τa(749), τa(865)

.. *aerosol model selection by (M1~9, 749, 865)*

τa(865) at $\mathbf{M_{select}}$

.. *convert by K-extension of the selected model*

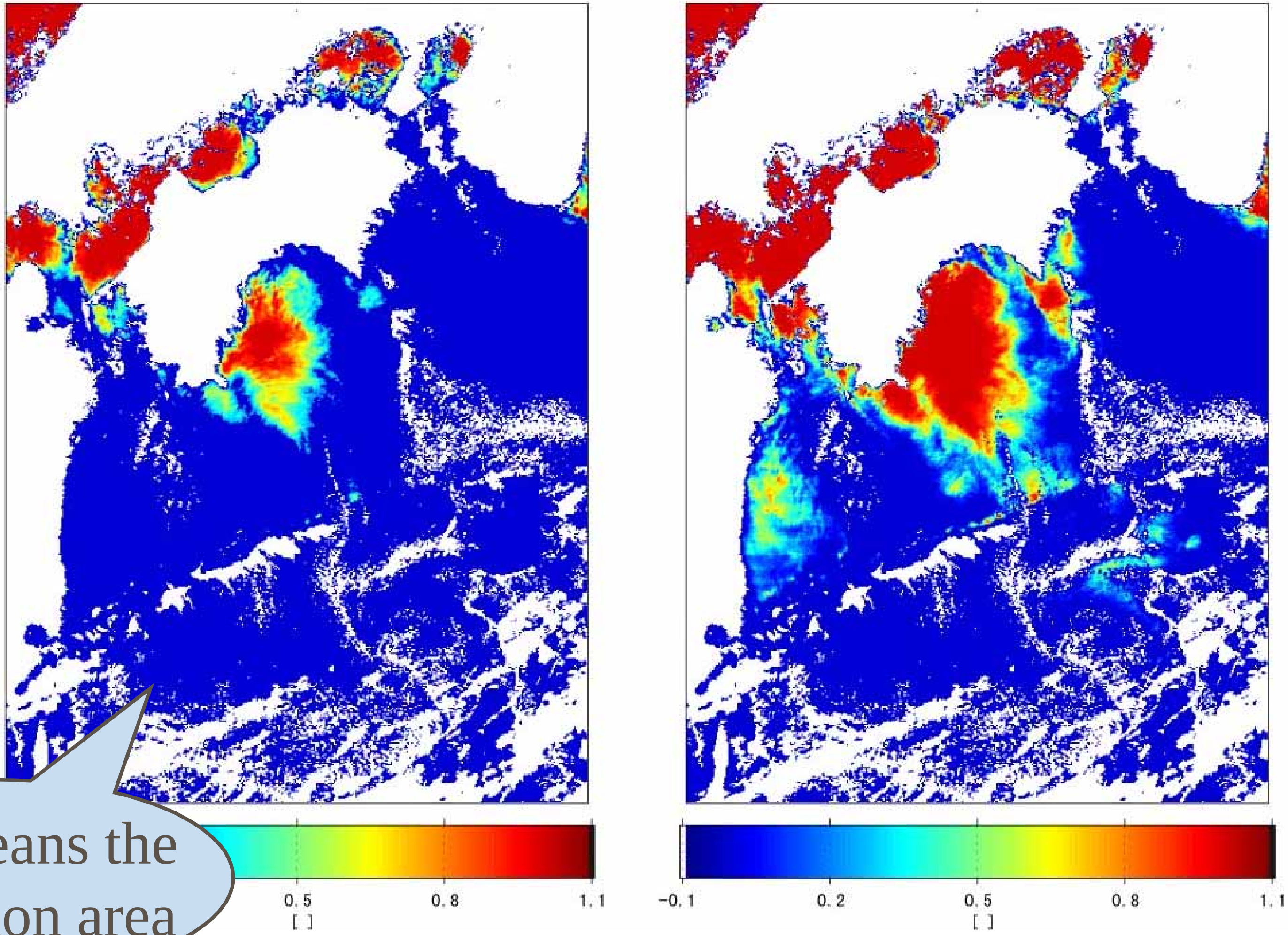
τa at in-water channels

.. *through L_w*

nLw, CHLA

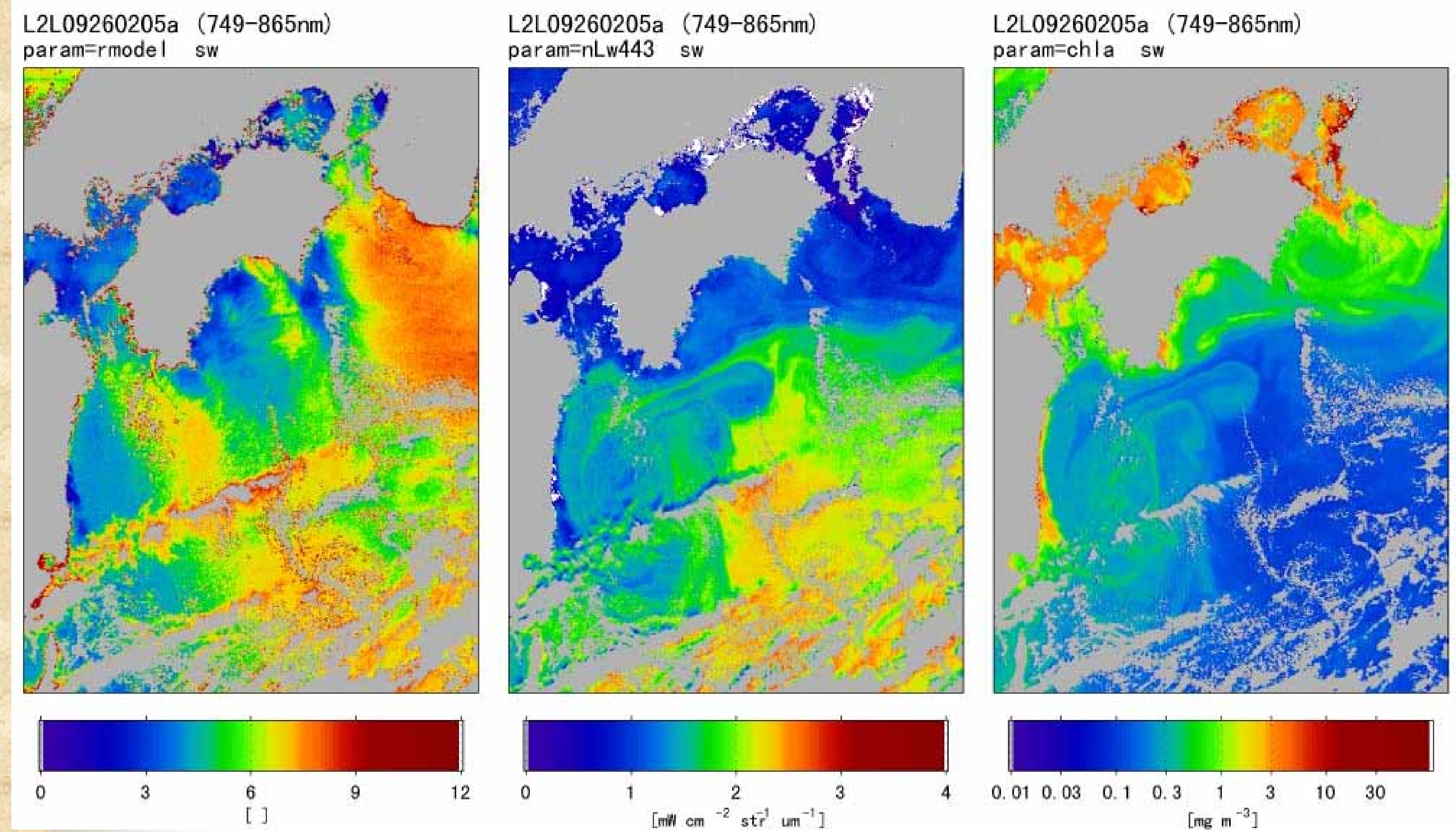
An example of weights in the witching

ratio1 for CH16 and CH16   ratio2 for CH18 and CH19



Blue means the saturation area

M_{select}, nLw443 and CHLA by the switching scheme



Switching Scheme

- We can use high gain bands without gaps by using the weighted switching schemes.
- Problems of noise and negative nLw are enlarged in the area switching to CH13-19.
- We should investigate their solutions.

Study of noise reduction

test the following three methods, a), b), and c)

Lt_{gli}^{noise}(CH13) and Lt_{gli}^{noise}(CH19)

↓ ..*Aerosol model selection by Lt_{gli}(CH13) and Lt_{gli}(CH19)*

M_{select}, $\tau_a 865$

..*a) 3×3 average of M_{select} and $\tau_a 865$*

↓ ..*b) 3×3 average of M_{select}*

..*c) 3×3 average of M_{select} excluding near cloud*

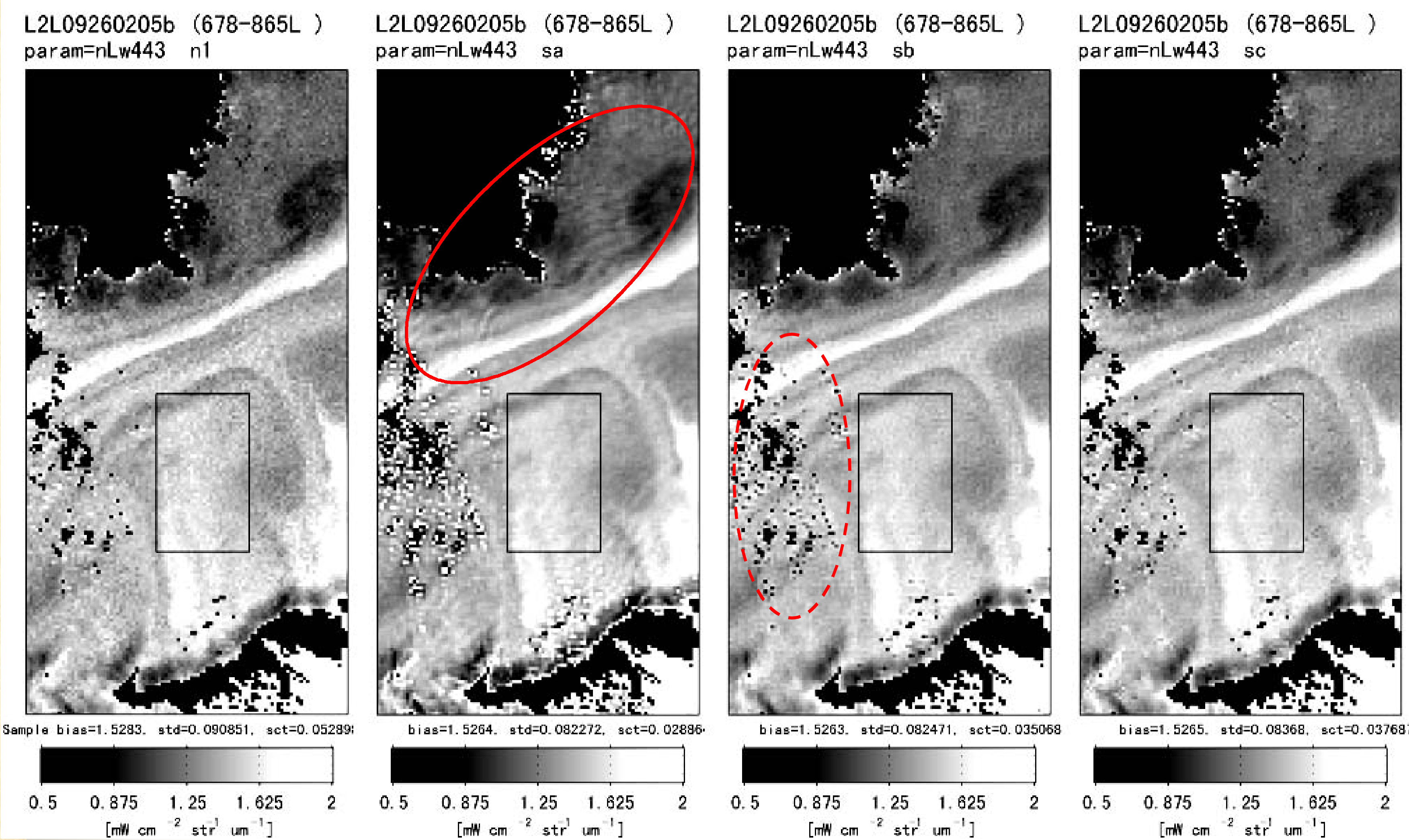
M_{select}^{smooth}, $\tau_a 865^{smooth}$ or M_{select}^{smooth}, $\tau_a 865$

↓ ..*Estimation of ρ_{a+ma} in visible bands*

nLw(λ) and CHLA

nLw 443 by CH13-19

original, applying noise reduction methods (a), (b) and (c)



Conclusion of the noise reduction

- If both τ_a and M_{select} are averaged, ripple pattern (by the atmosphere ?) appears in some cases.
- The best way seems to be averaging only M_{select} excluding near cloud, *i.e., scheme (3)*.
- Noise is decreased as follows,

  0.053 $\rightarrow$ (a) 0.029, (b) 0.035, and (c) 0.038 [$mW\ cm^{-2}\ \mu m^{-1}\ str^{-1}$]

A Study of Negative nLw problem

modify M_{select} to avoid that ρ_w(412nm) become negative

Lt_{gli}(CH13 and CH19)

↓ ..*Aerosol model selected by the normally*

M_{select}, τ_a865 at nine models

↓ ..*calculate ρ_w at 412nm*

$\rho_w(412)$

↓ ..*if $\rho_w(412) > 0.005$; modify M_{select} to adjust $\rho_w(412)=0.005$*

M_{select}^{adj}, τ_a865 at M_{select}^{adj}

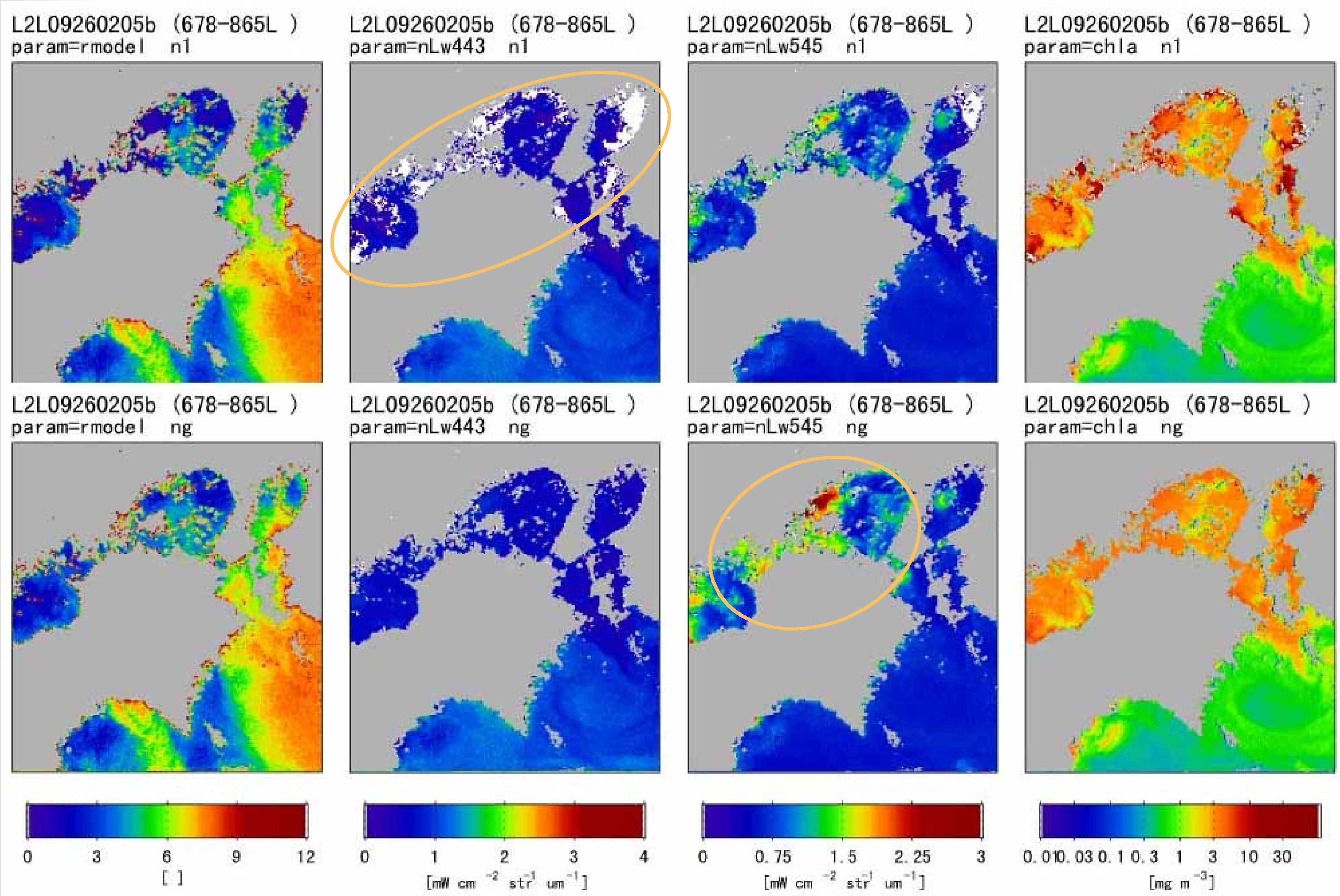
↓ ..*Estimate ρ_{a+ma} in visible bands*

nLw(λ) and CHLA

M_{select}, nLw443, nLw545 and CHLA by original and the M_{select}-adjustment schemes

Original

M_{select}-adjustment



A study of negative nLw problem

- By modifying M_{select} as avoiding negaitve ρ_w(412nm), M_{select} and nLw close to values expected by the original bands, CH16-18.
- M_{select}^{adj} gives better results but not correct ones. This approach should be applied as (e.g.,) first guess of NIR in iteration schemes.

Remained problems and schedule around the ADEOS-2 launch

Items to be solved	*2001/ 05-06*	*07-09*	*10-12*	*2002/ 01-03*	*04-06*	*07-09*	*10-12*	*2003/ 01-03*	*04-06*	*07-09*
	Events		*◆GLI WS*	*◆Launch*	*◆First image* *◆Regular observation mode→*			*◆EOC data release*		
Study of iteration method	------------------------------				------------------					
LUT modification	---------------------									
Operational experiments	other satellite data --------------------				GLI data--					
Modify codes & documents	----------------------					revise-------------				
710nm water vapor correction			--------			----------- ?…				
763nm oxygen correction			--------			----------- ?…				
Study of multiple-NIR methods	--- --- --- --- --- --- ---				---?…					
Cal/Val of GLI L1B and L2					A/B/C -------------D--					
Applying alternative algorithm					a/b---b/c---d-------d/eb/c----------------------------------					

a) Operation test using CH16-18 and CH13-19 independently → *First-light image*

b) Noise reduction, stripe-noise reduction, avoiding negative-nLw

c) Relative correction of NIR, applying switching schemes → *First version (First image?)*

d) Study of atmospheric correction by other candidates,
CH15-19 (considering water-vapor absorption),
CH17-19 (considering oxygen absorption), CH19-24, and CH19-26

e) Decide optimal scheme from on-orbit data → *Next versions*

Conclusion

- We can achieve the minimum goal (very primal usage) just using CH13-19 instead of CH16-18.

- We recommend the following solutions to satisfy research activities and data promotion.

1. Switching CH16-18 and CH13-19 around the saturation radiance smoothly (switching scheme).

2. Additional noise should be reduced by averaging 3 pixel ×3 line of M_{select} when using CH13-19.

3. We should improve negative-nLw problem by modification of M_{select} by ρ_w at the shortest VIS band with an iteration scheme, for example.

Conclusion

next steps

- We may have the following items for the next step.

1. Optimization of construction of look-up table, which is used to derive M_{select}, and interpolation ways from the table.
2. Evaluation of in-water optical models in the iteration process, and ways to be applied to the GLI operation code.

The report of the alternative algorithm study has been open from GLI Web PI's Door

Activity of NASDA GLI Calibration 4th Group

Members of the 4th Group

Application & science

H. Murakami chair

Y. Mitomi, M. Yoshida, S. Kawamoto, R. Higuchi,

I. Asanuma, N. Matsuura

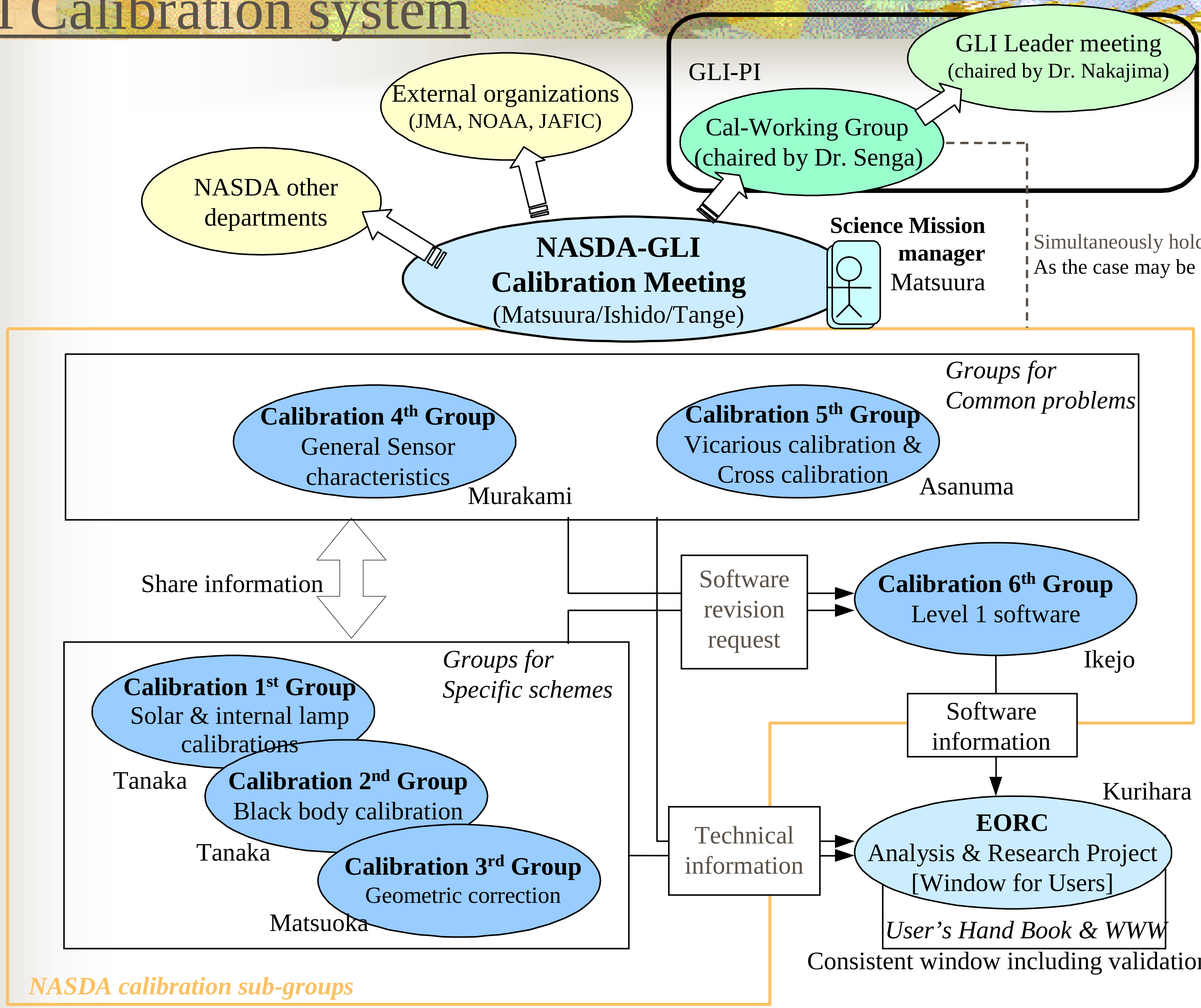
Sensor development

K. Tanaka, S. Kurihara, K. Isono, Y. Okamura, Y. Tange

A. Ikejyo, H. Yatagai, Y. Ishido

Ground system

GLI Calibration system



Cited from K. Tanaka (31 Oct., 2001)

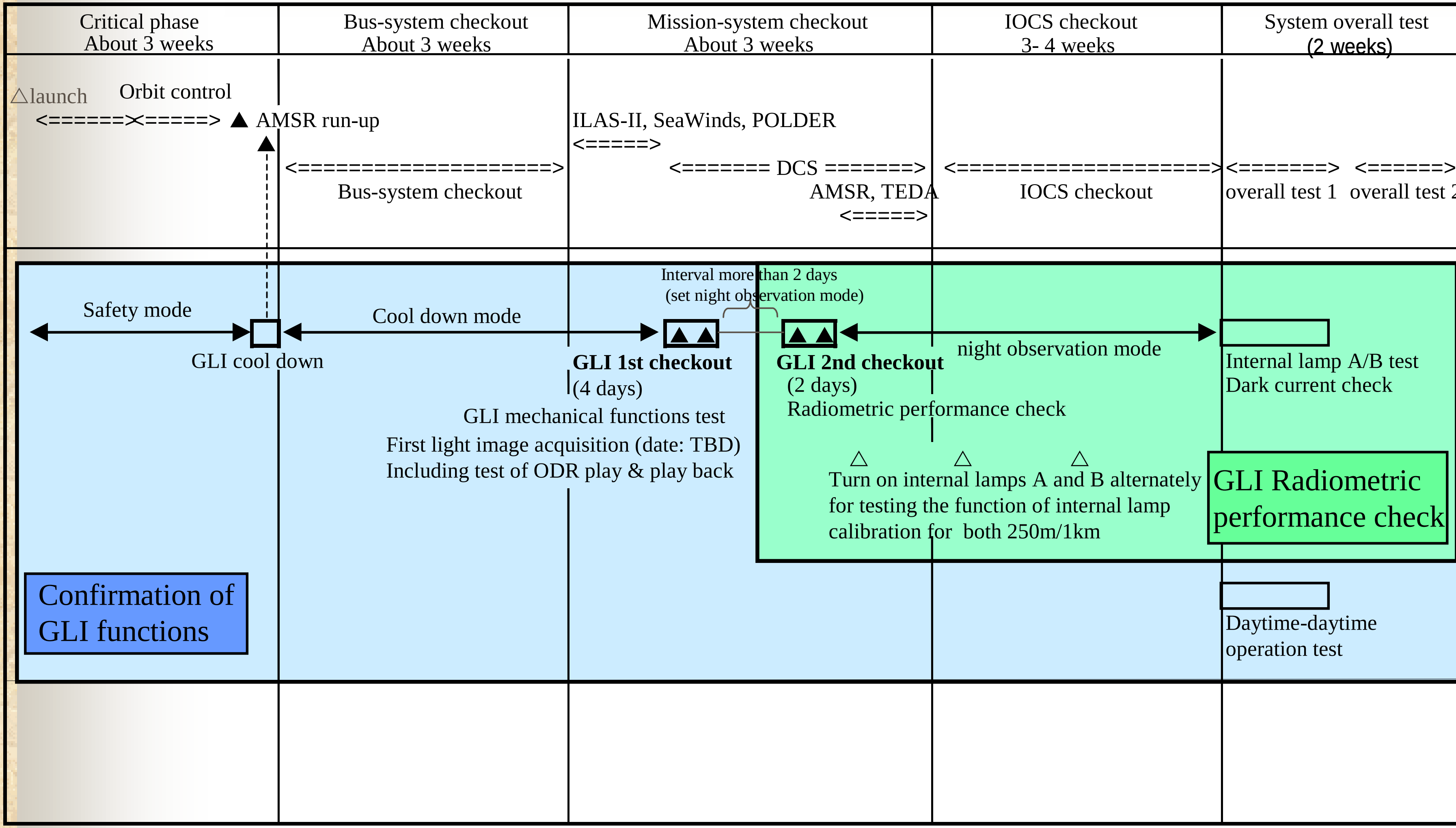
Objectives in the 4th Group

- Objectives of GLI NASDA Calibration teams are to **improve Level 1B data** for satisfying user requirements (both PI and the public) as soon as possible.
- Objectives of our 4th group are to **evaluate and monitor GLI characteristics and improve Level 1 operation algorithm** except for internal lamp, solar and black body calibrations (they are in charge of 1st and 2nd groups). In addition, the 6th group discuss common problems and help NASDA calibration teams (1st to 6th groups) share common information.
- The 4th group is planning which items should be done, and how can we evaluate **on-board calibration functions and optical performance of GLI during the initial checkout period**. We will carry out them as a member of the GLI initial checking team.

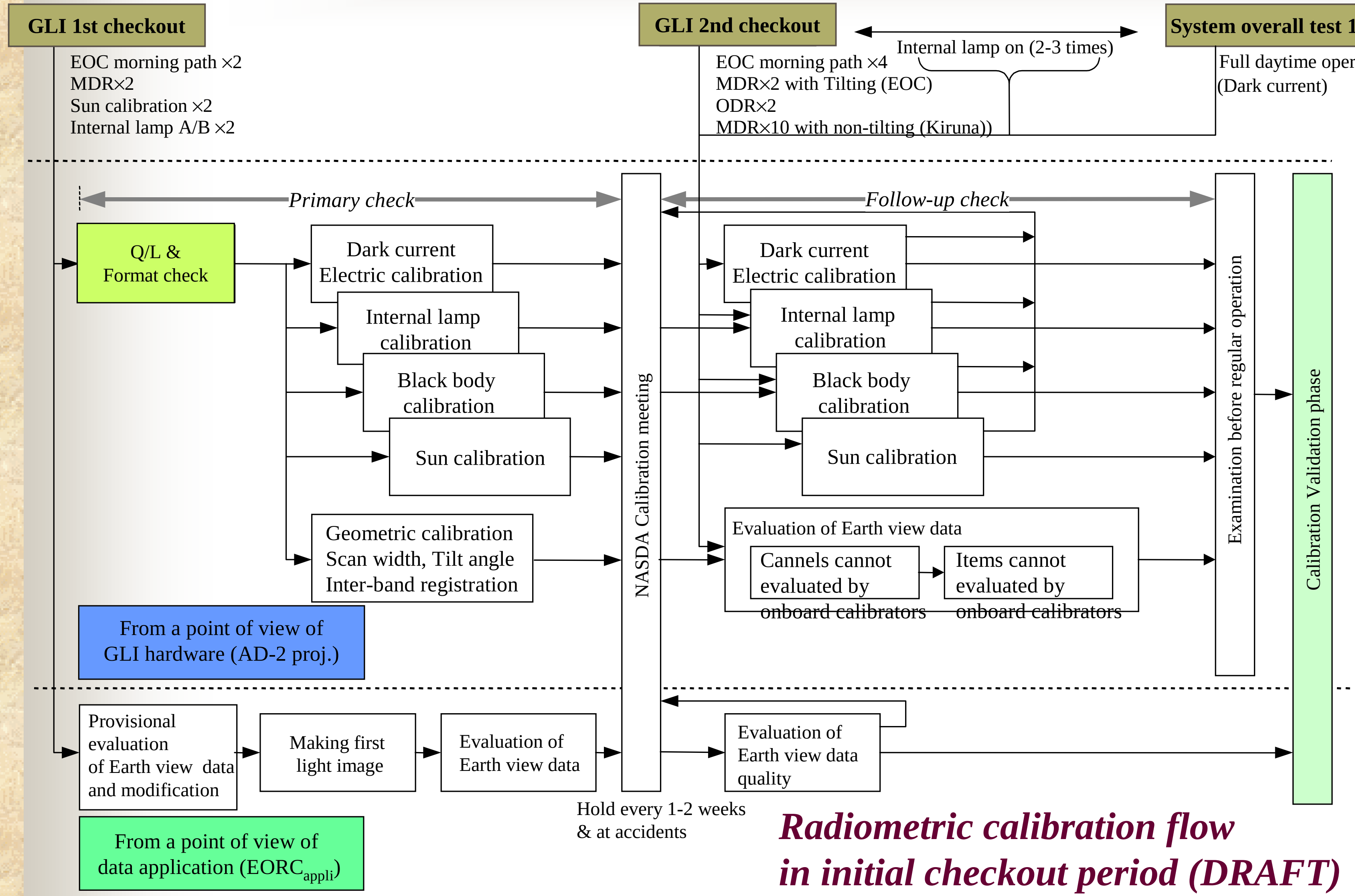
Items to be done

Items	*Data source*
Scan mirror reflectance depending on its sides and angle	PFT, on-board calibration, and earth observation data
Detector correlated noise	PFT, on-board calibration, and earth observation data
Periodic noise of MTIR	PFT, on-board calibration, and earth observation data
SNR and NEΔT	PFT, on-board calibration, and earth observation data
Dynamic range, Over-saturation and linearity	PFT, and earth observation data
Continuity between piece-wise linear gains	PFT, and earth observation data
Transitional response, stray light, cross talk and MTF	PFT, and earth observation data
Stability of dark current	PFT, deep space, and night time observation data
Stability of sensor and on-board monitors	Telemetry and monitor outputs

ADEOS-2 GLI Initial checkout outlines



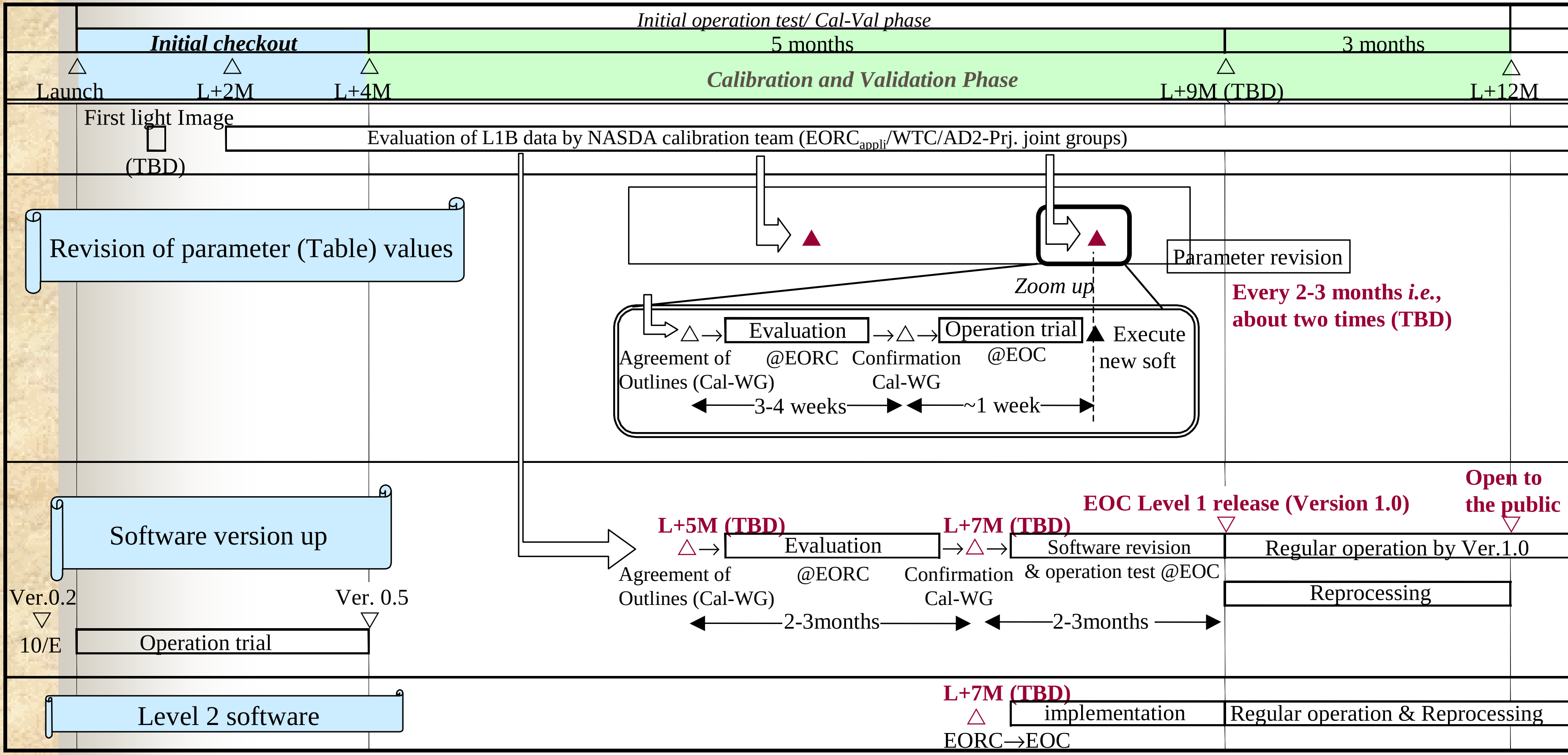
Flowchart of GLI initial checkout



Radiometric calibration flow in initial checkout period (DRAFT)

Cited from K. Tanaka (31 Oct., 2001)

Calibration activity in GLI cal/val phase (~L+12M) & Implementation schedule to Level 1 software (DRAFT)



An example of activities
Correction of detector correlated noise

The detector correlated noise is **defined as residual errors after Level 1 processing**. The correction applies to radiometric corrected but detector-not-resgistrated Level 1B radiance, $L_{i,j}^{original}$.

$$L_{i,j}^{corrected} = a_{i,j} \cdot L_{i,j}^{original} \qquad \ldots(1)$$

i: detector (1<i<12 ×2: mirror sides A/B are included in the i)

j: band (1<j<36),

The "$a_{i,j}$" assumed to be related with input radiance, bands j, detectors (× scan-mirror sides) i, and scan-mirror angle ϕ, *i.e*,

$$a_{i,j}=b0_{i,j}+b1_{i,j}\cdot L_{i,j}+b2_{i,j} / L_{i,j}+b3_{i,j}\ L_{i,j}^{2}+b4_{i,j}\cdot \phi +b5_{i,j}\cdot \phi^{2}. \quad \ldots(2)$$

Detector correlated noise

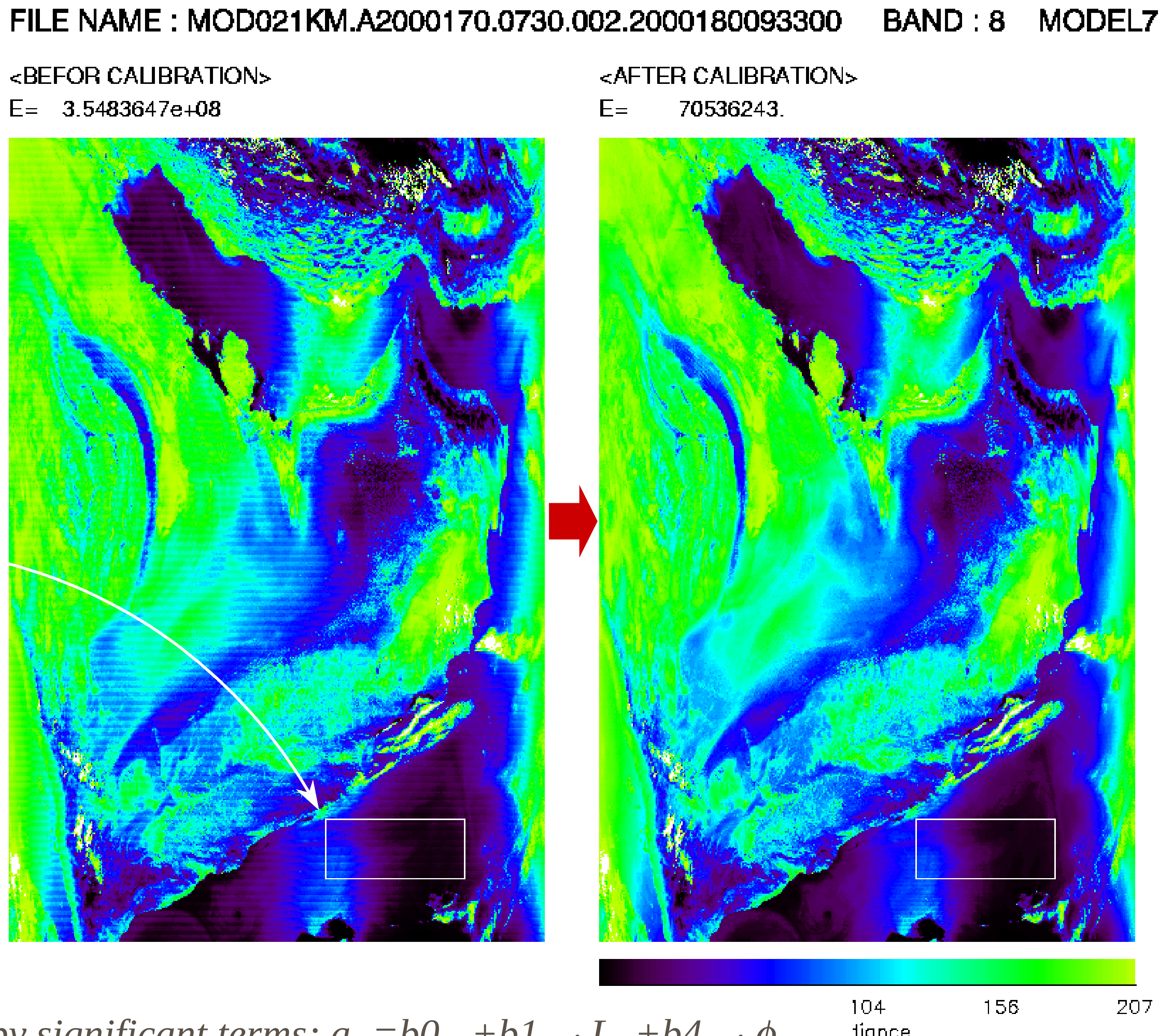
Calibration

The "$b^*_{i,j}$" are estimated by followings.

1. Sampling smooth areas n (L lines and K pixels, normally 200×200) from earth observations of detector-non-resgistrated L1B (1<n<N).
2. Derive $a_{i,j,n}$ Minimizing E, and averaged radiance $\overline{L_{i,j}^{original}}_{n}^{K\times L\ average}$ for each sub-image n.

$$E = \sum_{l=0}^{L-1} \left\{ \sum_{k=0}^{K-1} a_{i,j,n} \left(DN_{l,k}^{j,n} - O^{j,n} \right) - a_{i+1,j,n} \left(DN_{l+1,k}^{j,n} - O^{j,n} \right) \right\}^2 \ldots (3)$$

3. Examine statistical significance of terms, $b^*_{i,j}$ in polynomial expression *(1)* using $a_{i,j,n}$.
4. Derive $b^*_{i,j}$ by fitting to *(1)* excluding insignificant terms $b^*_{i,j}$.



Sample;
MODIS
412nm

(K=350, L=149)

sqrt(E/(K×L)) is decreased from original (i.e., a=1)

82.2

W/m²/str/μm

↓

36.7

W/m²/str/μm

Expression by significant terms; $a_{i,j}=b0_{i,j}+b1_{i,j}\cdot L_{i,j}+b4_{i,j}\cdot \phi$

Working Schedule