# Vicarious calibration of ADEOS-2 GLI and Terra/Aqua MODIS using global data set for multi-sensor ocean-color applications

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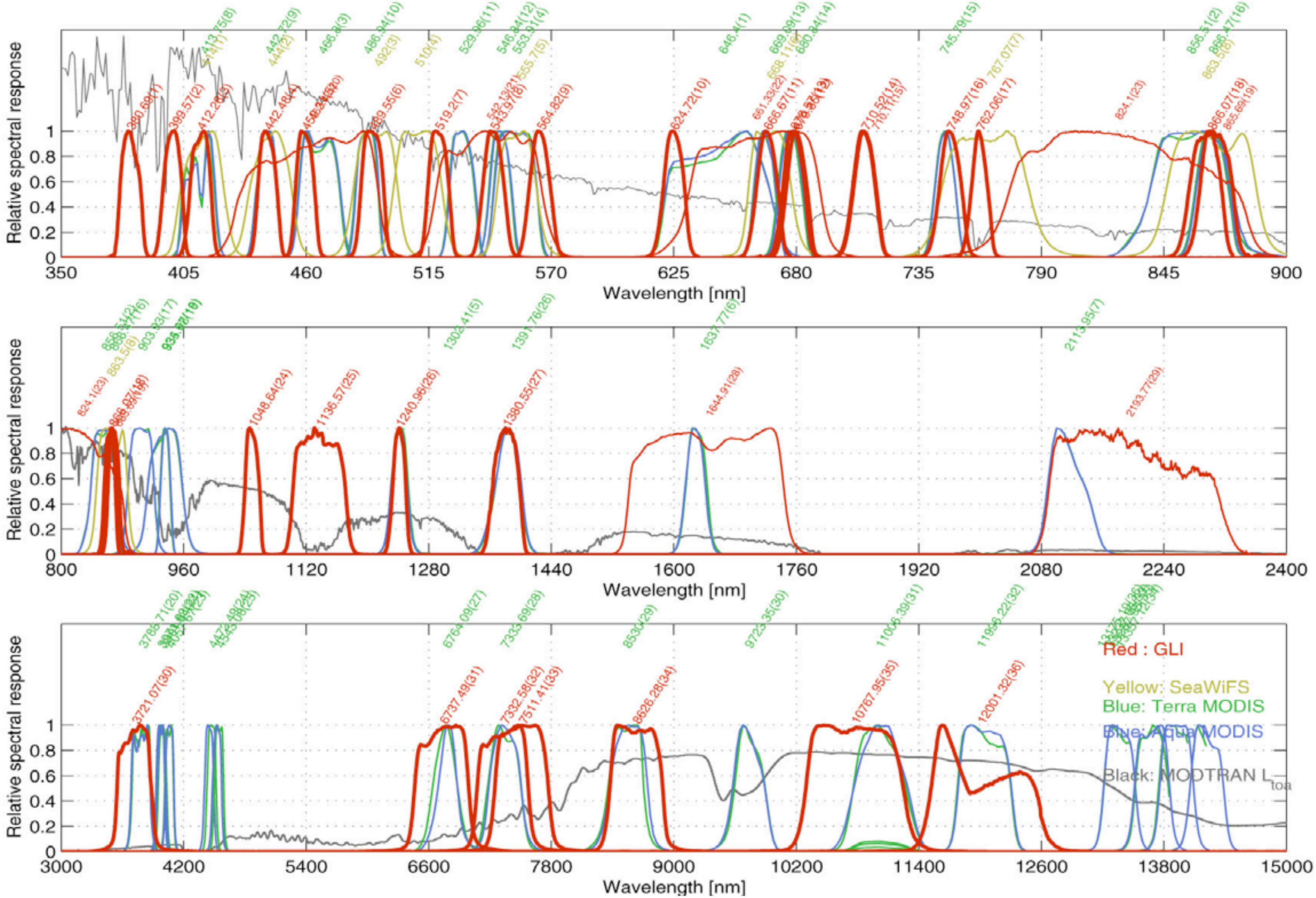
# 1. Introduction

- Consistent data sets from multi-satellite sensors are important.
- Generally, vicarious calibration coefficients (*Kvc*) for ocean color are derived using in-situ observations. However, it has problems;
  - In the early phase, we cannot obtain enough number of in-situ (match-up) observations.
  - Ground measurement error and sub-pixel structure can be a serious problem.
- We tried to derive *Kvc* globally using global GLI (or MODIS) $L_{TOA}$, SeaWiFS nLw (8 days mean), and GLI atmospheric correction look-up tables (LUTs) of Rayleigh, ozone, solar irradiance, and aerosols calculated by radiative transfer code (RSTAR5b).
- Consistent algorithms are used for the atmospheric correction and in-water retrievals (considering GLI and MODIS channel responses).
- The global *Kvc* could detect dependencies on observation date ($t$), scan-mirror incident angle ($\varphi$), and latitude (*Lat*).
- Operation tests of ocean-color products applying the *Kvc*.

# 2.1 Response function of GLI and MODIS



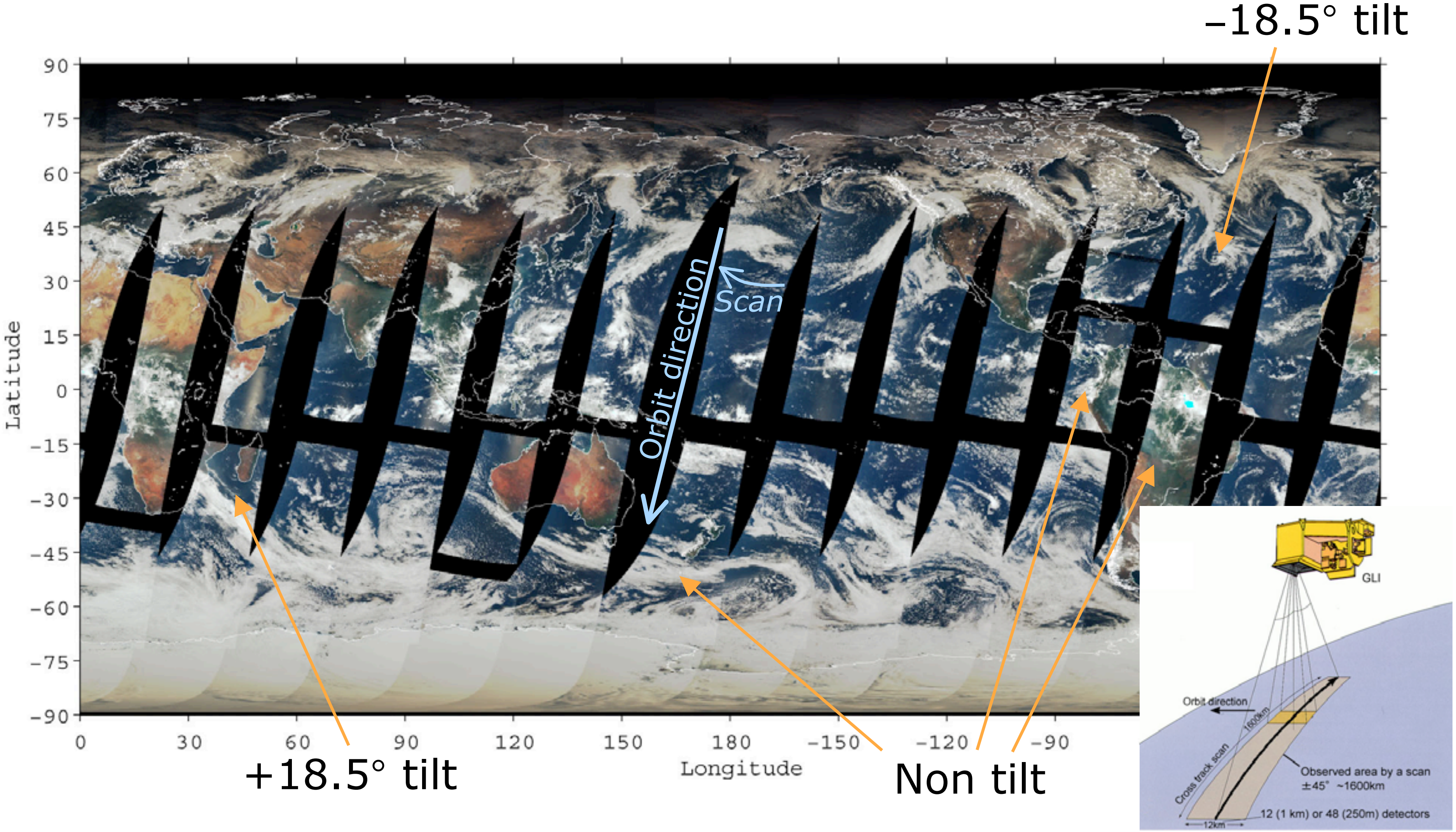
*(the GLI response data are in http://suzaku.eorc.jaxa.jp/GLI/cal/res/)*



# 2.2 Example of one-day coverage

## GLI L1B on 17 Oct. 2003

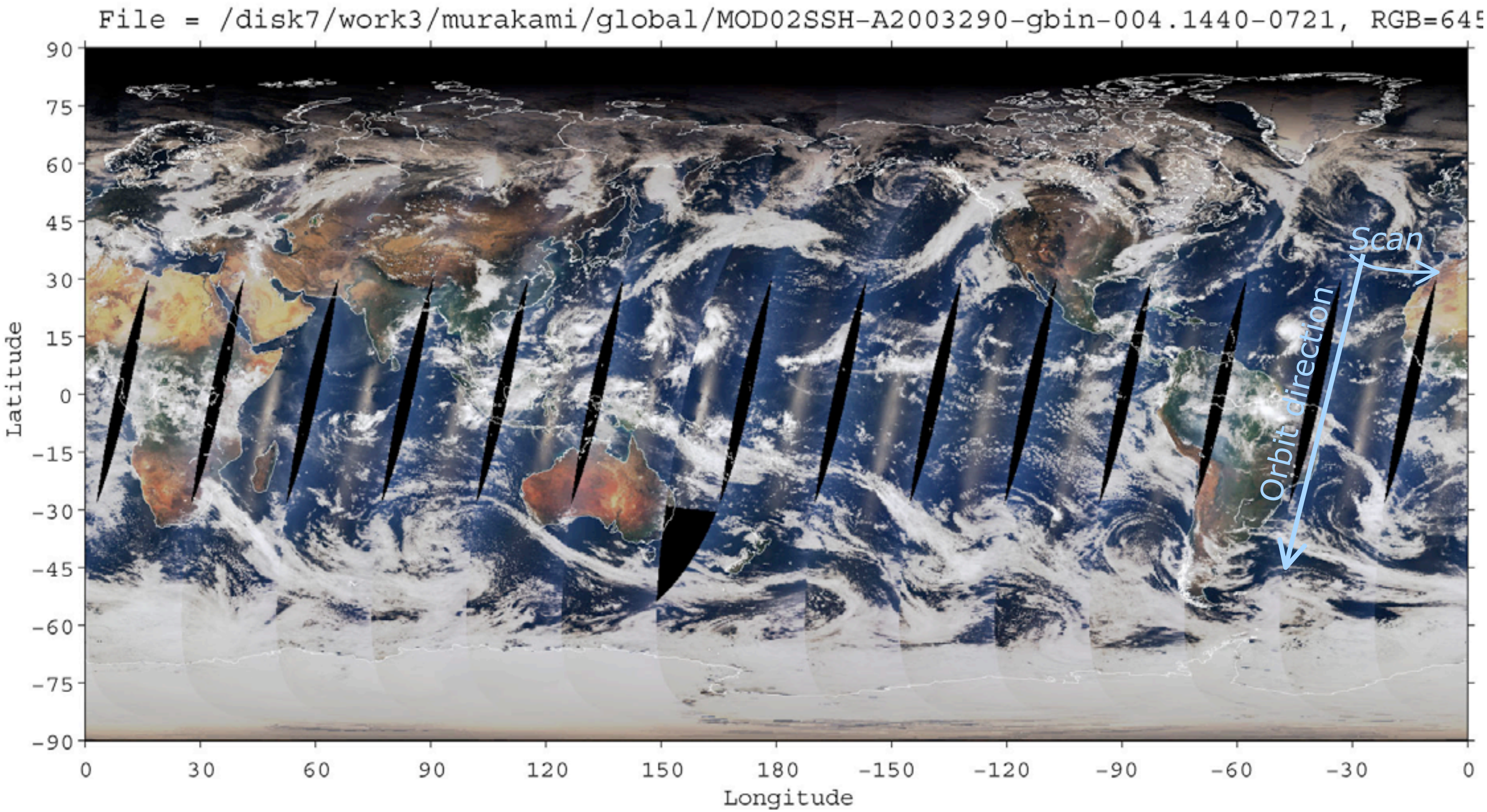
Revolutions per day: 57/4, Inclination: 98.6°
Descending local time: 10:30am, Altitude: 803km, period: 6060sec
(all daily global images and binary data are in http://suzaku.eorc.jaxa.jp/GLI/cal/browse/index.html)



# 2.3 Example of one-day coverage

## Terra MODIS 5-km data (MOD02SSH) on 17 Oct. 2003

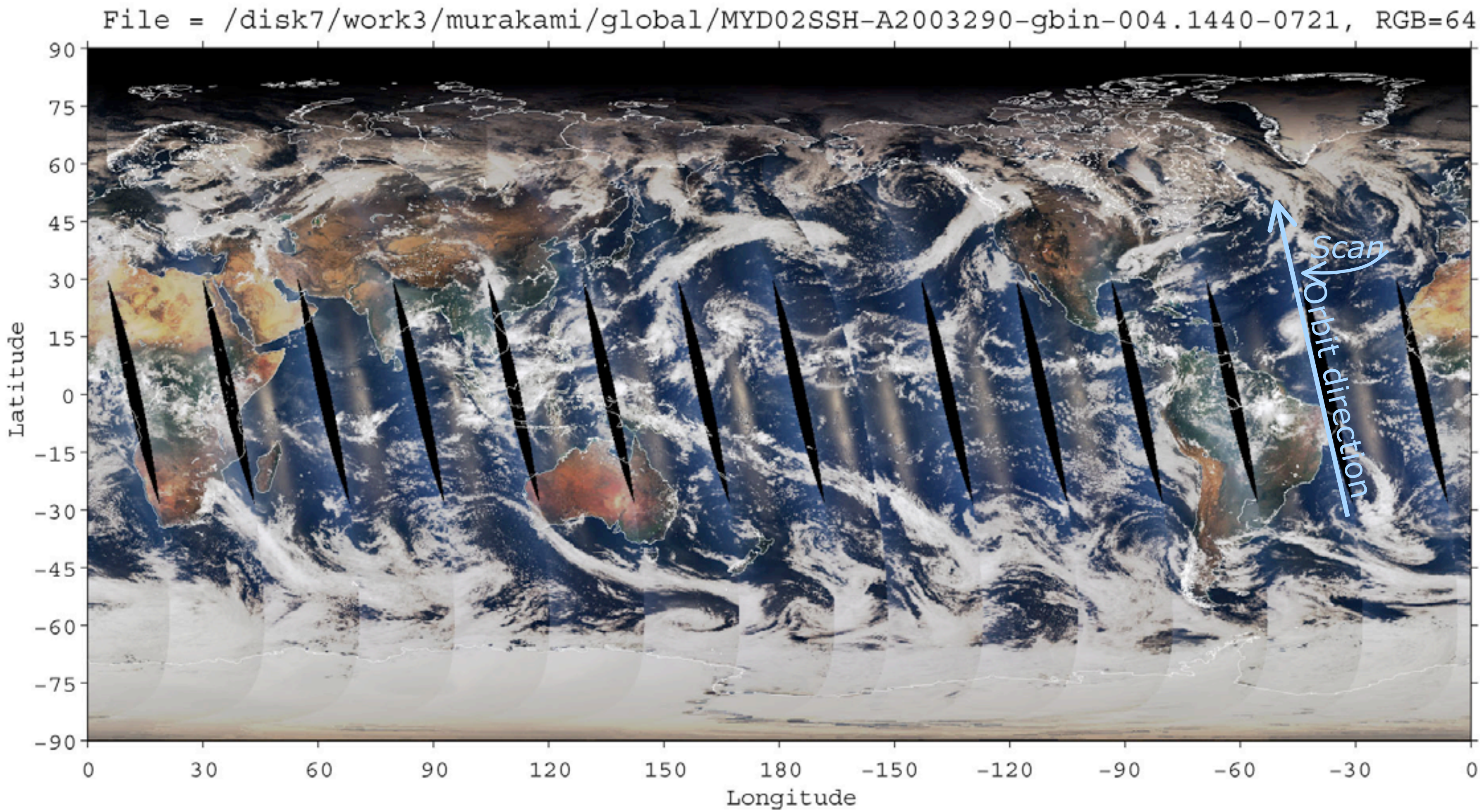
Revolutions per day: 233/16, Inclination: 98.2°
Descending local time: 10:15-10:45 AM (descending),
Altitude: 705km, period: 5928sec



# 2.4 Example of one-day coverage

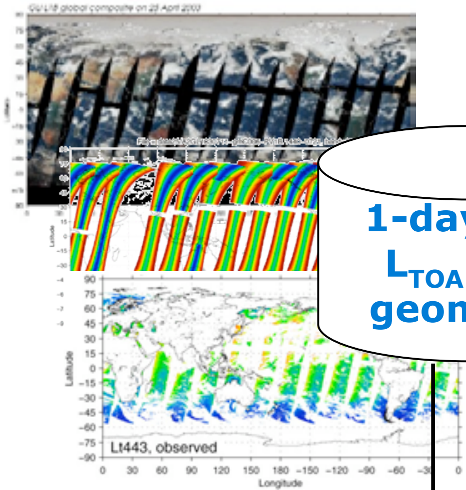
## Aqua MODIS 5-km data (MYD02SSH) on 17 Oct. 2003

Revolutions per day: 233/16, Inclination: 98.2°
Descending local time: 01:15-01:45 PM (ascending),
Altitude: 705km, period: 5928sec



# 3.1 Operation Flow of Global Vical

***Sample days*** GLI (16days): 02/06, 03/20, 04/06, 04/22, 05/08, 05/24, 06/09, 06/25, 07/11, 07/27, 08/12, 08/28, 09/13, 09/29, 10/15, 10/24 in 2003
Terra (25 days): 01/02, 01/18, 02/03, 02/19, 03/07, 03/23, 04/08, 04/24, 05/20, 05/26, 06/11, 06/27, 07/13, 07/29, 08/14, 08/30, 09/15, 10/01, 10/16, 10/17, 10/18, 10/19, 11/02, 11/18, 12/04 in 2003
Aqua (4days): 04/24, 06/27, 08/30, 10/17 in 2003

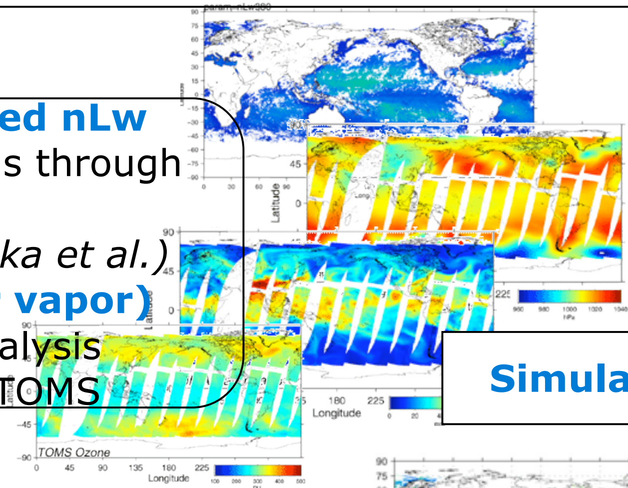



**1-day L1B $L_{TOA}$ and geometry**

Fix two NIR CHs for estimating aerosol optical thickness ($\tau_a$) and aerosol model ($M_{select}$)
CH13 and 19 (678 and 865nm) for GLI
CH15 and 16 (747 and 866nm) for Terra/Aqua MODIS

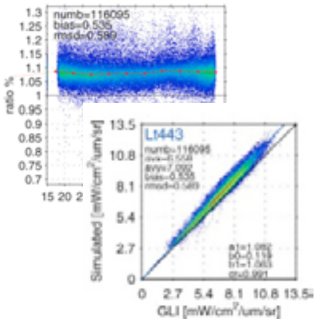
LUTs

**Aerosol model selection**
by GLI atmos corr. Look Up Tables ($\tau_a \rightarrow L_{TOA}$)
for GLI and MODIS channel responses

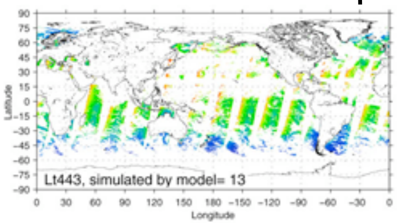



**SeaWiFS 8-day binned nLw**
interpolated to GLI bands through an
***in-water model*** *(Tanaka et al.)*
**Pressure (and water vapor)**
by JMA objective analysis
**Column ozone** by TOMS

**Simulated $L_{TOA}$**




Derive **correction coefficients** by comparison between GLI L1B and simulated $L_{TOA}$.



# 3.2 nLw interpolation

We estimated nLw($\lambda_{GLI}$: 380, 400, 412, 443, 460, 490, 520, 545, 565, 625, 666, 670, 680, 678 and 710 nm) from nLw($\lambda_{SeaWiFS}$: 412, 443, 490, 510, 555, and 670nm).

1) Derive $nLw_{interp}$($\lambda_5$: 412, 443, 460, 520, and 545 nm), which are used for deriving in-water parameters, by **wavelength linear interpolation** from nLw($\lambda_{SeaWiFS}$).

2) **Estimate in-water parameters**: suspended solid concentration (SS) and Colored Dissolved Organic Matter (CDOM) using $nLw_{interp}(\lambda_5)$ and GLI empirical algorithms.

3) **Estimate $nLw_{model}(\lambda_{SeaWiFS})$ by an in-water model** using the IOSS, CDOM and SeaWiFS Level-3 CHLA.

4) **Derive correction factor $R(\lambda_{SeaWiFS})$,**

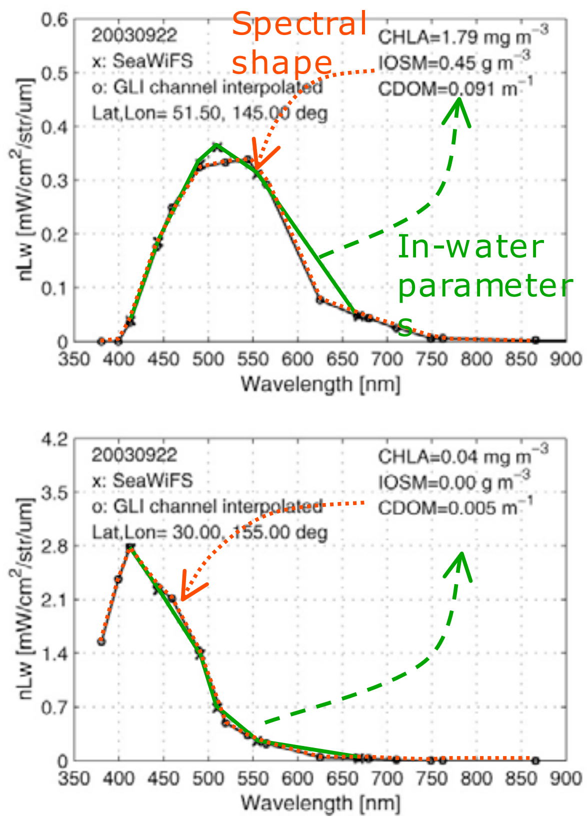
$R(\lambda_{SeaWiFS}) = nLw(\lambda_{SeaWiFS}) / nLw_{model}(\lambda_{SeaWiFS})$.

5) **Derive $R(\lambda_{GLI})$** by linear interpolation from $R(\lambda_{SeaWiFS})$.

6) **Estimate $nLw_{model}(\lambda_{GLI})$ by an in-water model** using the IOSS, CDOM and SeaWiFS Level-3 CHLA product.

7) **Derive realistic $nLw_{model}(\lambda_{GLI})$** by factor $R(\lambda_{GLI})$.

$nLw(\lambda_{GLI}) = nLw_{model}(\lambda_{GLI}) \times R(\lambda_{GLI})$.




Figures show examples of the inter/extrapolation in the cases of high CHLA (1.79mg/m$^3$) and low CHLA (0.04mg/m$^3$).

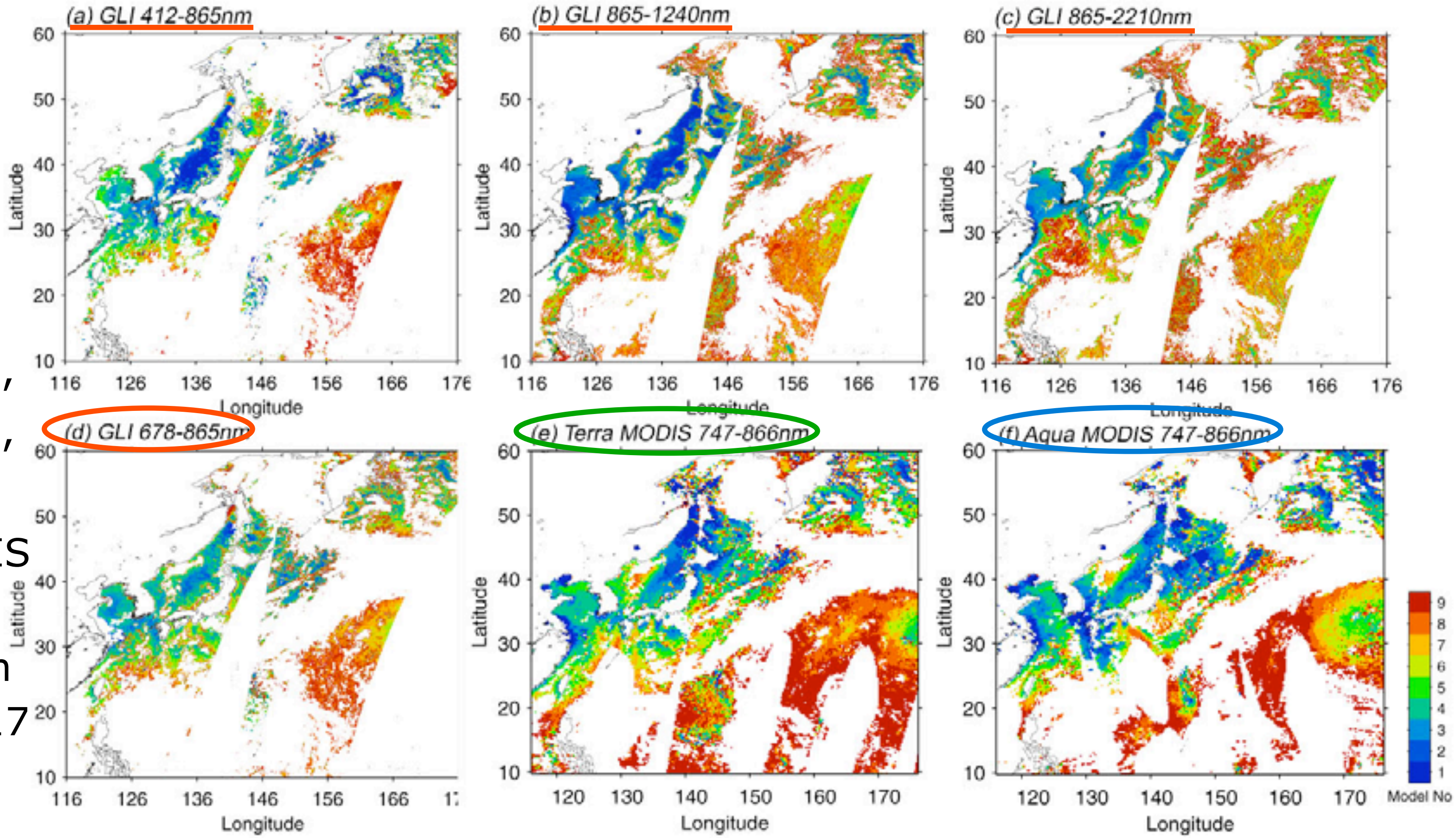
# 3.3 Aerosol model selection

*Selected models ($M_{select}$) by different channels*

We can use any channel pairs; we selected NIR channels used in the atmospheric correction: CH13-19 (678 and 865 nm) and CH15-16 (747-865nm) for the GLI and MODIS respectively.

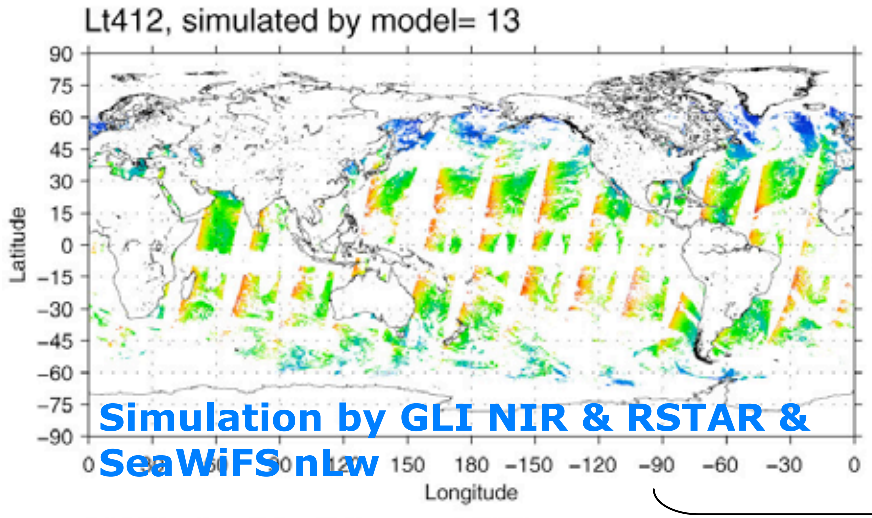
*Kvc* at the channels are 1.0 (they made reasonable aerosol properties).

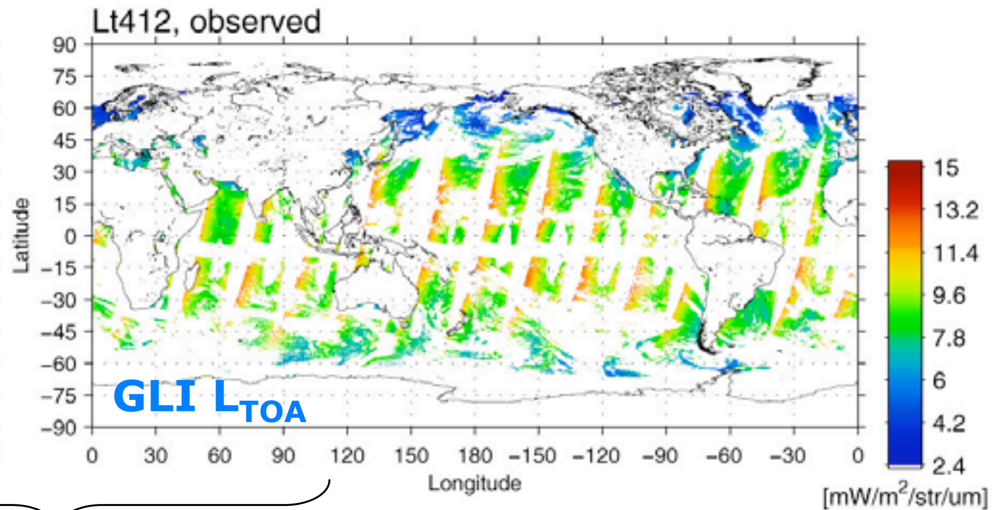
$M_{select}$ by GLI 412-865nm, 865-1240nm, 865-2210nm, 678-865nm, and by MODIS 747-865nm around Japan in 2003/10/17

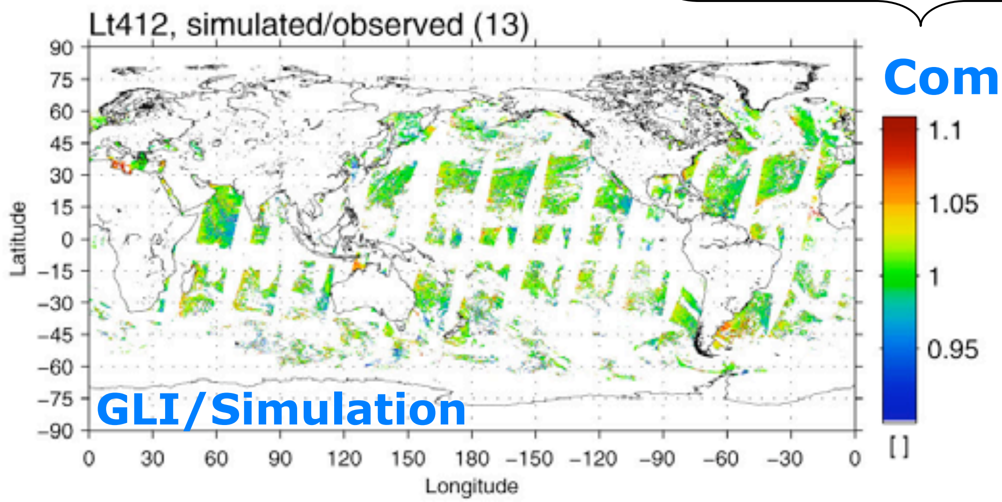


# 4.1 Results of GLI

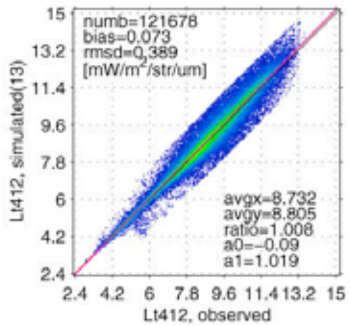
*Simulated and observed GLI CH03 $L_{TOA}$ (412nm) on 2003/10/15 (by CH13-19B)*



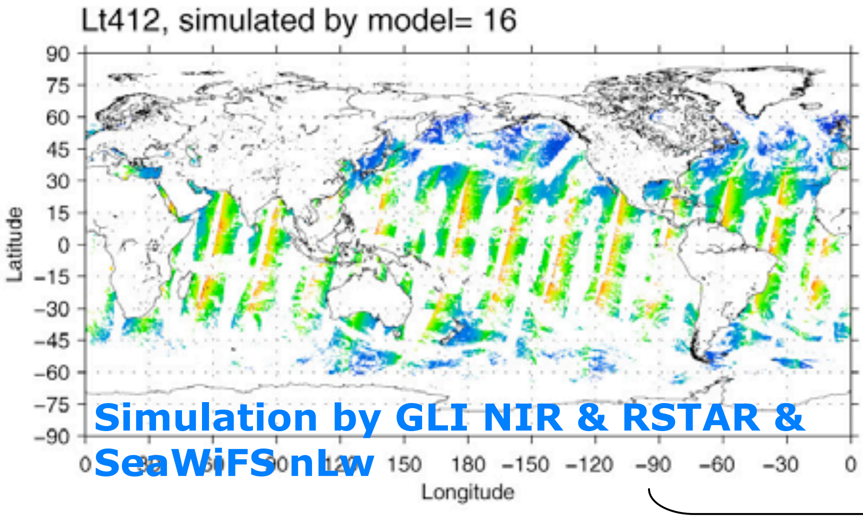




**Compare → Vicarious coefficients**

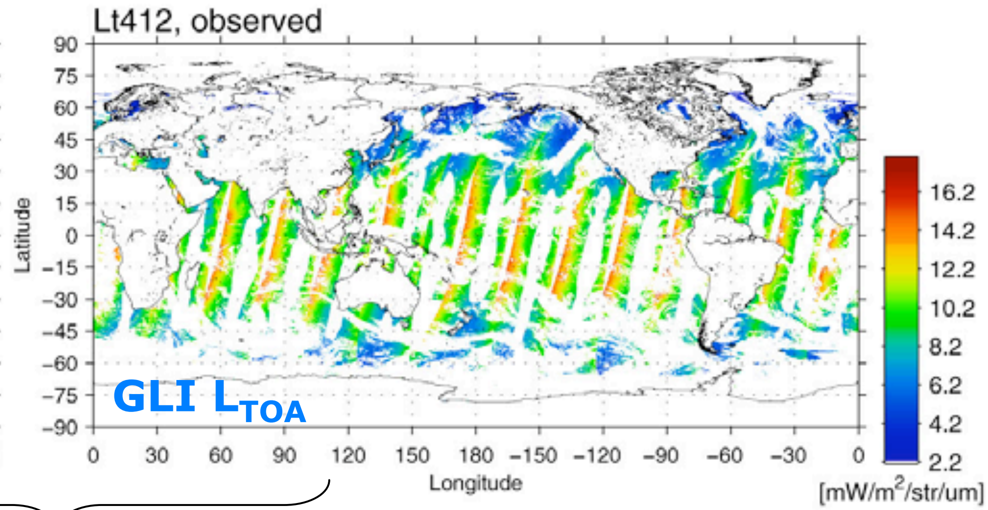


# 4.2 Results of Terra MODIS

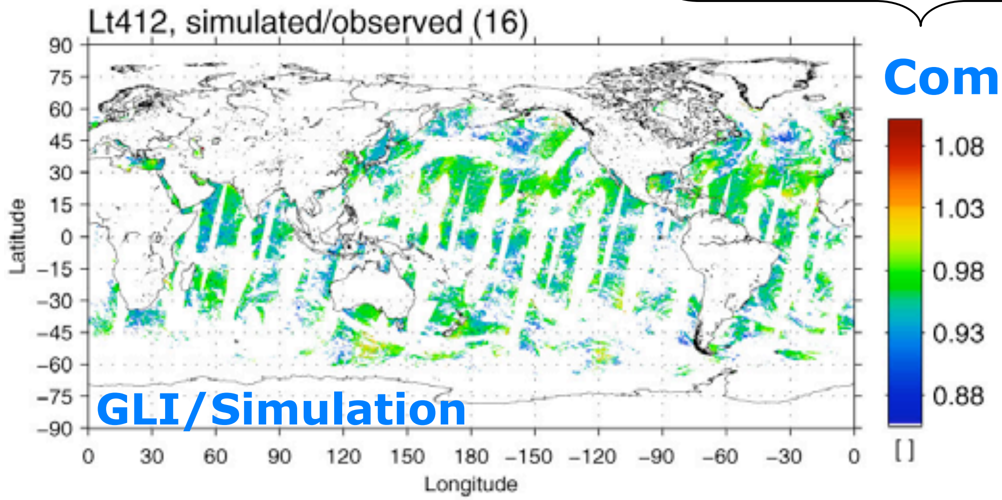
*Simulated and observed Terra MODIS CH08 $L_{TOA}$ (412nm) on 2003/10/17 (by CH15-16)*




**Simulation by GLI NIR & RSTAR & SeaWiFS nLw**

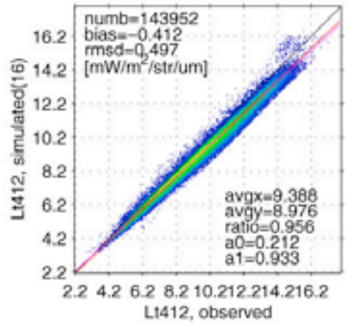



**GLI $L_{TOA}$**



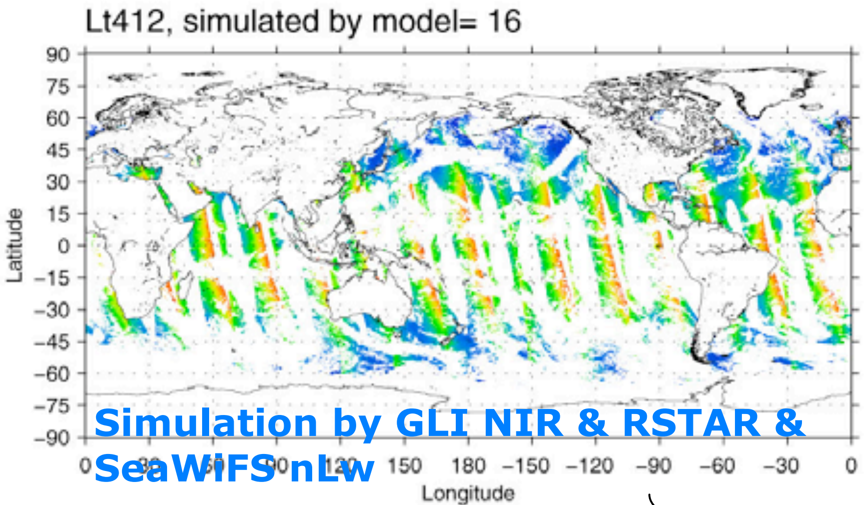

**GLI/Simulation**

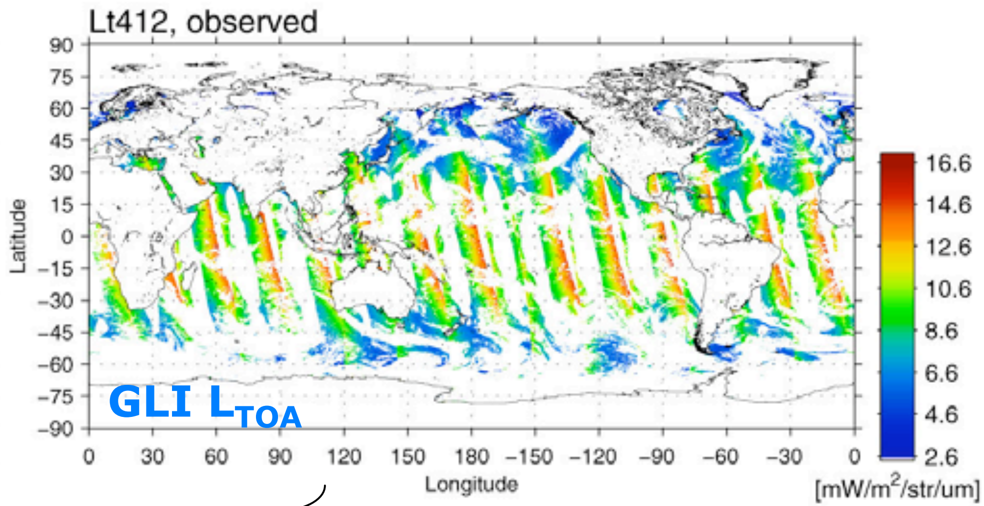
**Compare → Vicarious coefficients**



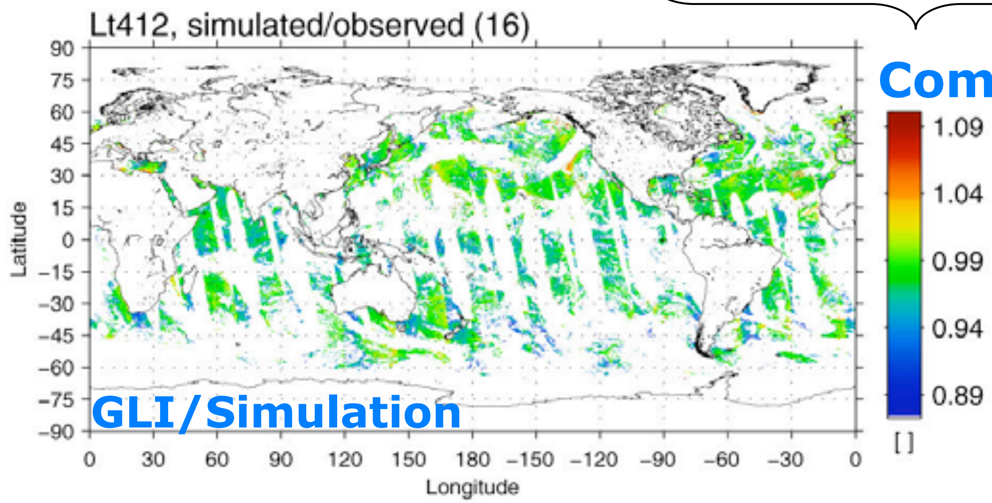
# 4.3 Results of Aqua MODIS

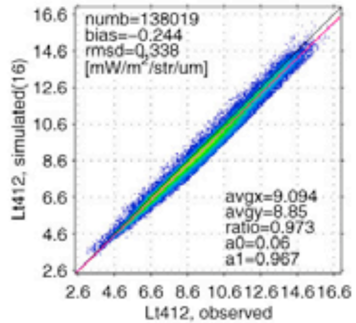
*Simulated and observed Aqua MODIS CH08 $L_{TOA}$ (412nm) on 2003/10/17 (by CH15-16)*




Compare → Vicarious coefficients

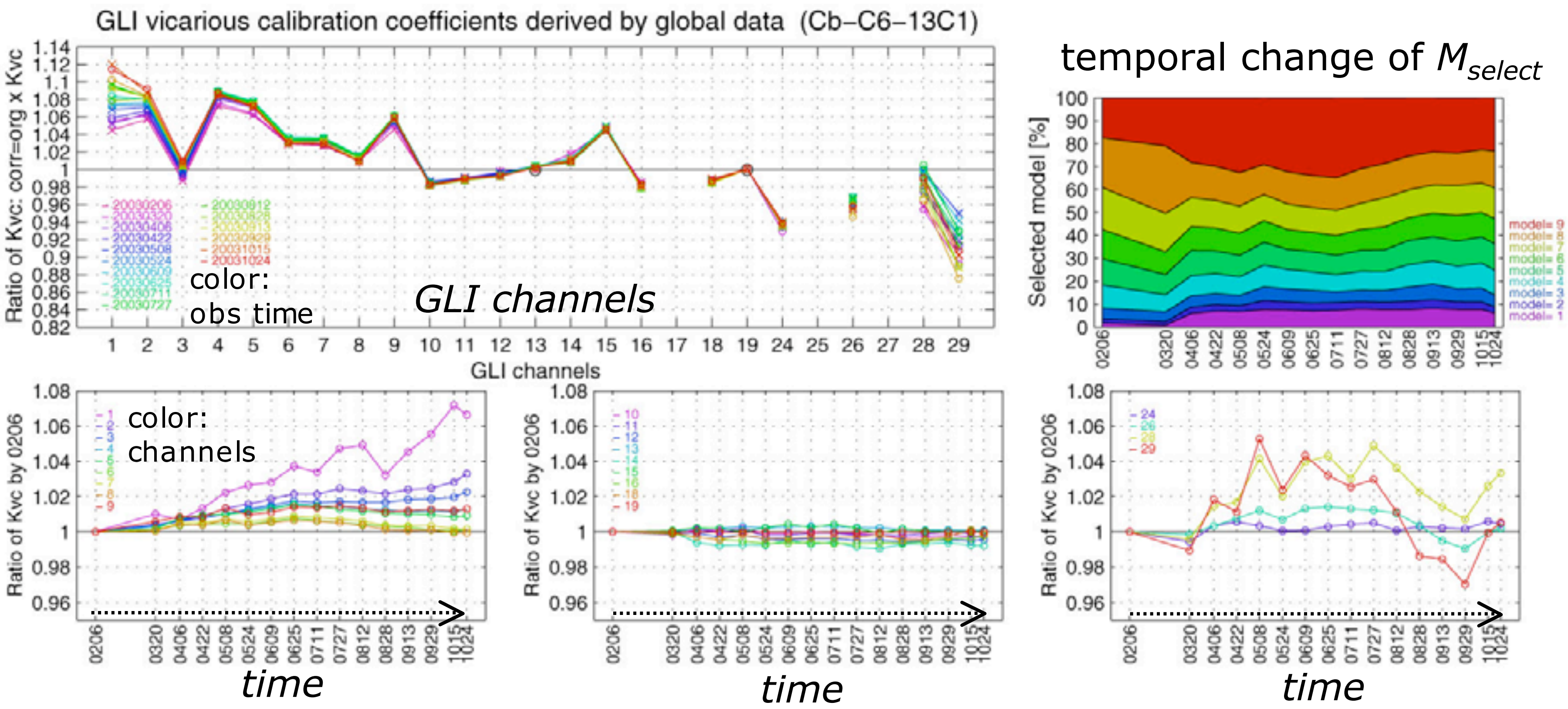


# 4.4 Results *GLI Kvc*

## Coefficients based on CH13-19B (global average)

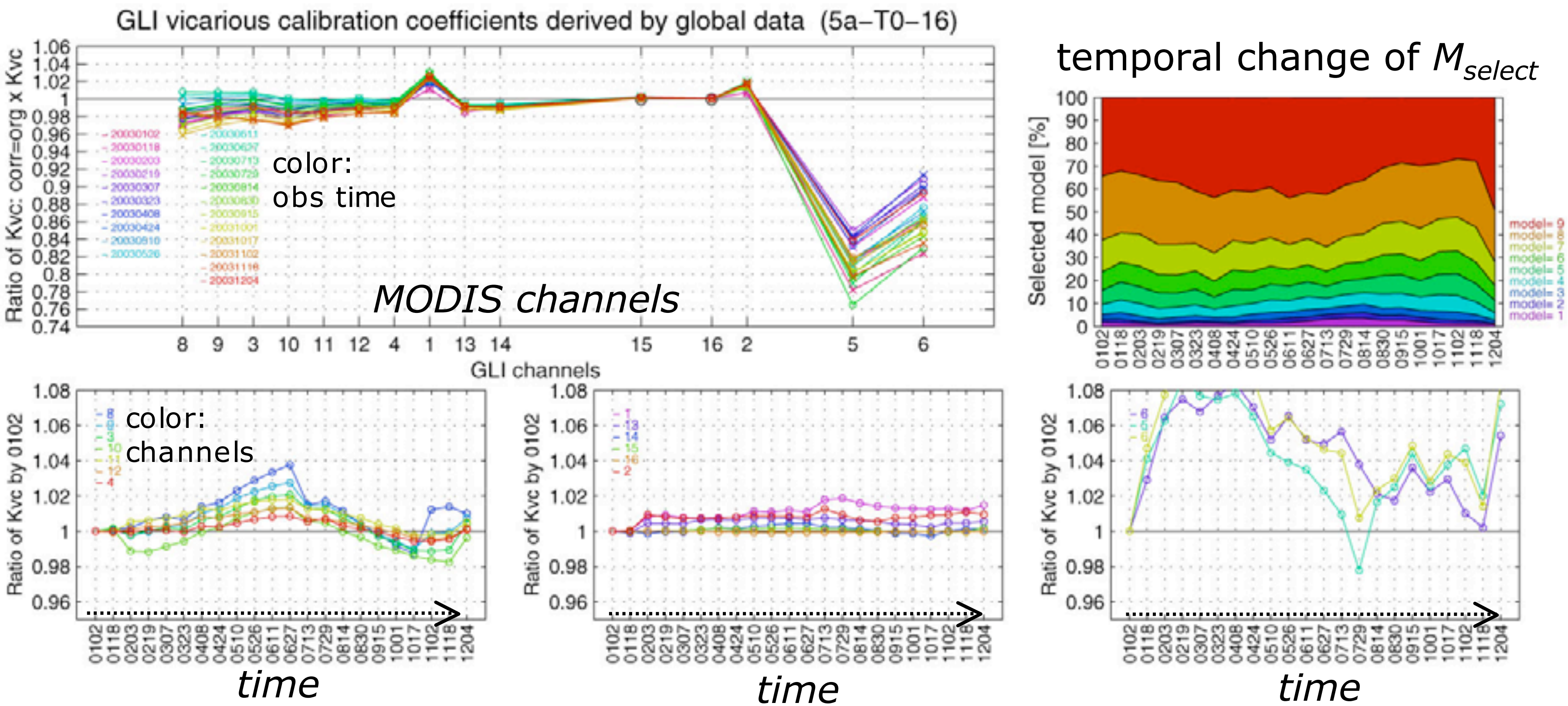
- *About 5% change (increase) at CH01.*
- *Unrealistic large scatter in SWIR channels (due to simulation sensitivity)*



# 4.4 Results *Terra MODIS Kvc*

## Coefficients based on CH15-16 (global average)

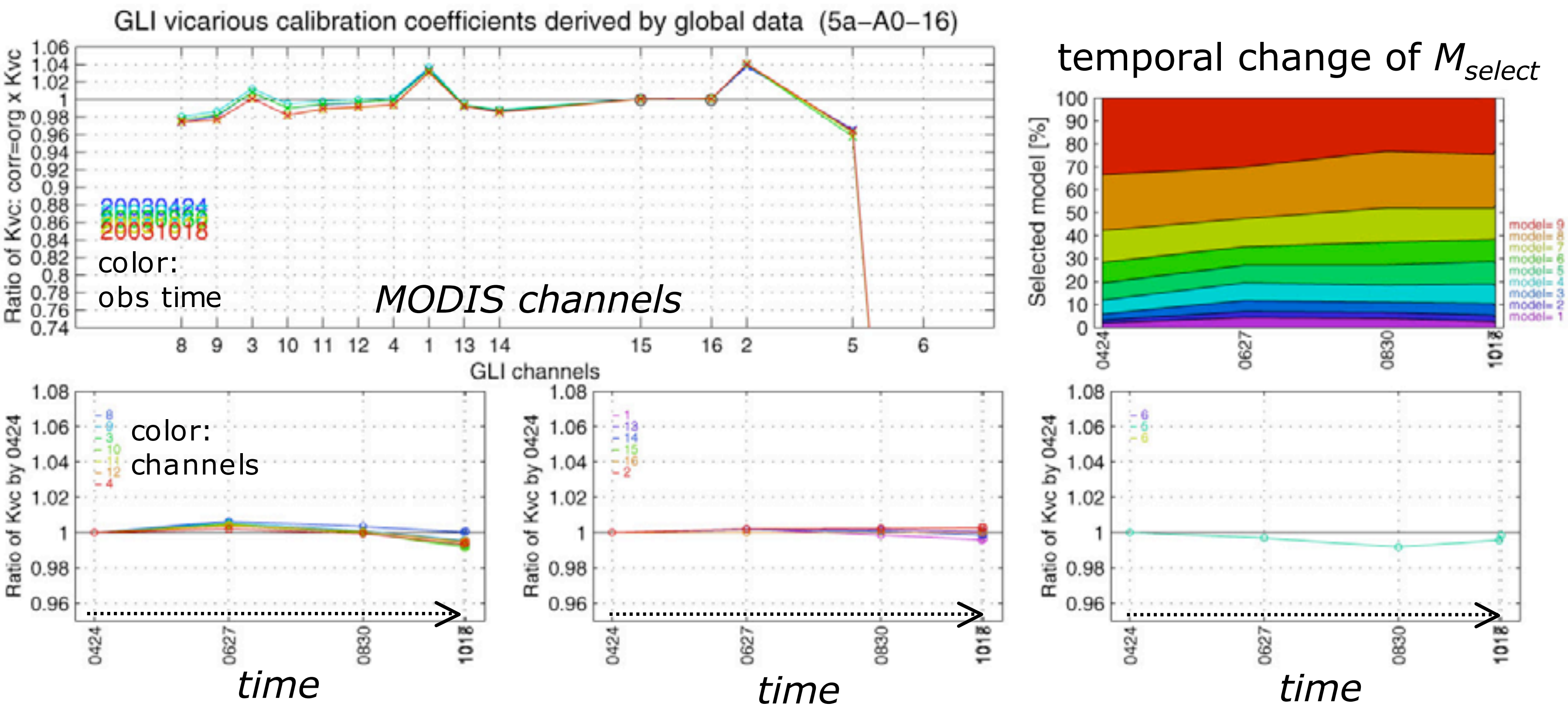
- *About 3% change (cyclic?) at CH08-12 (blue-yellow).*
- *Unrealistic large scatter in SWIR channels (due to simulation sensitivity)*



# 4.4 Results *Aqua MODIS Kvc*

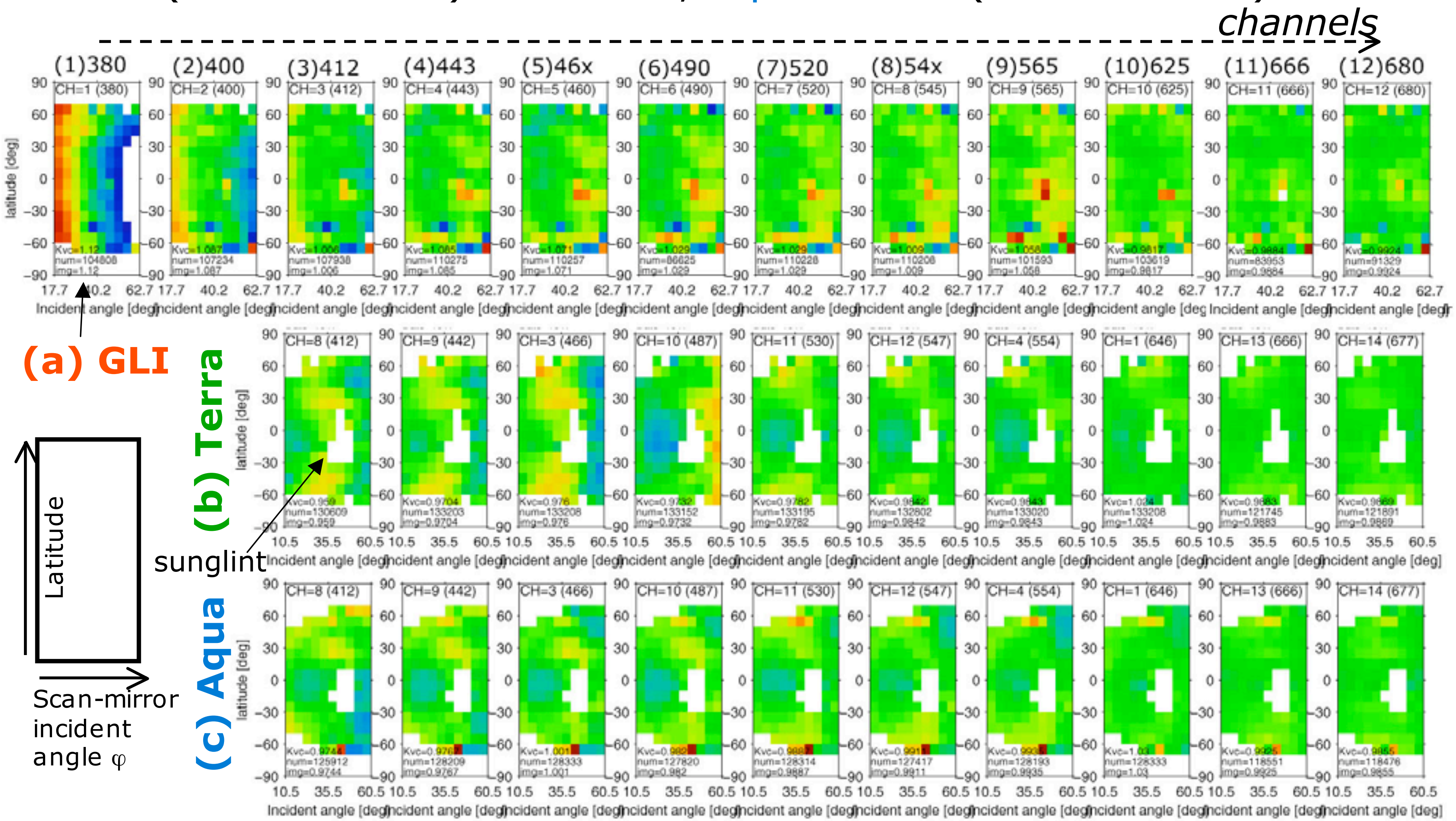
## Coefficients based on CH15-16 (global average)

- *Stable than Terra MODIS.*
- *No signal in CH6 (1640nm)*

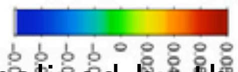


# 4.5 Results *Latitude and scan-mirror incident angle*

GLI (15 Oct. 2003) and Terra, Aqua MODIS(17 Oct. 2003)



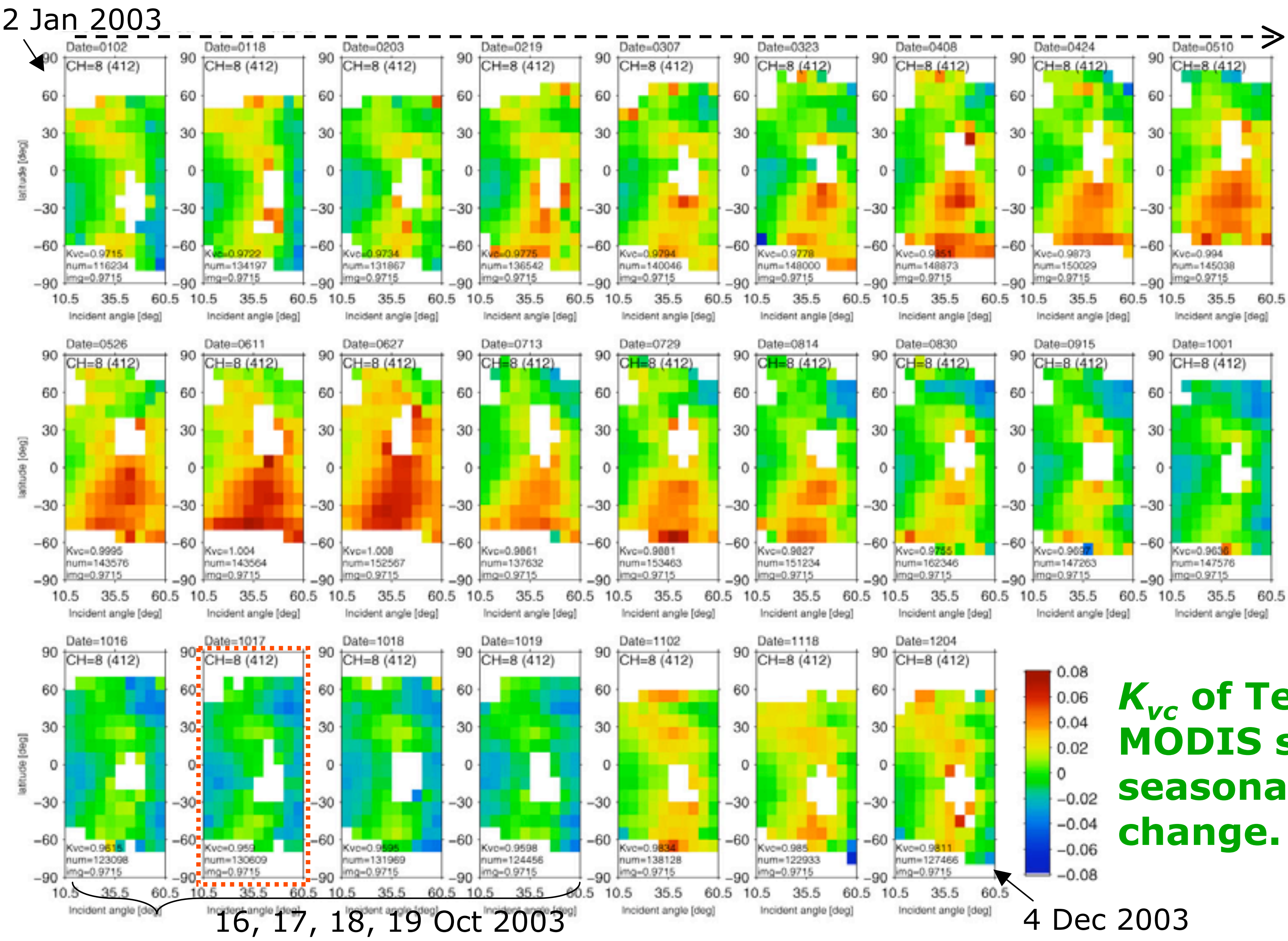

- ***Kvc* of GLI CH01-03 have $\varphi$ dependency**
- ***Kvc* of Terra MODIS are changed by sunglint position.**



Color is normalized by the average of each panel

# 4.5 Results; *Temporal change of Terra MODIS*

## Terra MODIS (MOD02SSH_004) 412nm (CH08) in 2003



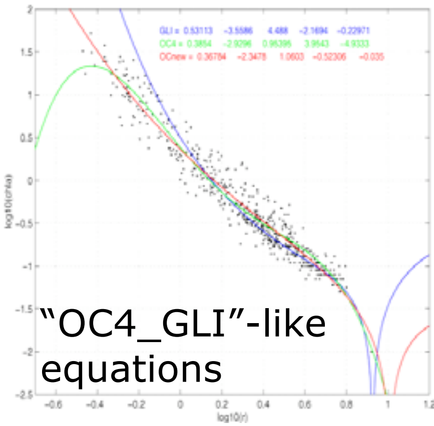

Color is normalized by the average of the first (upper left) panel.

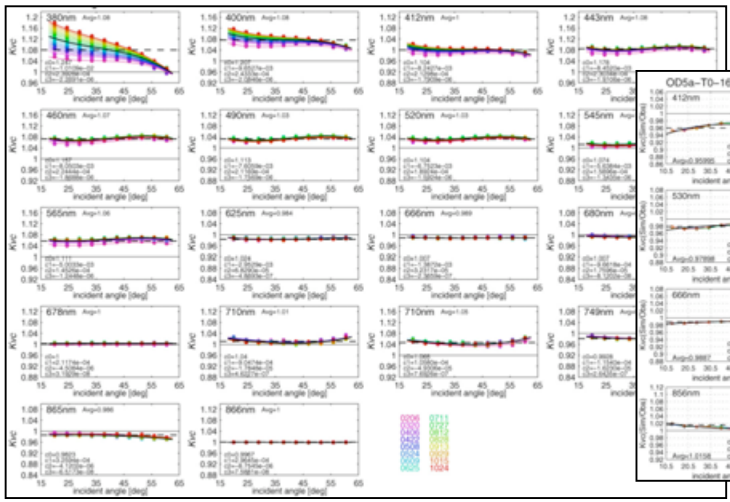
**$K_{vc}$ of Terra MODIS shows seasonal change.**

# 5.1 Product tests;

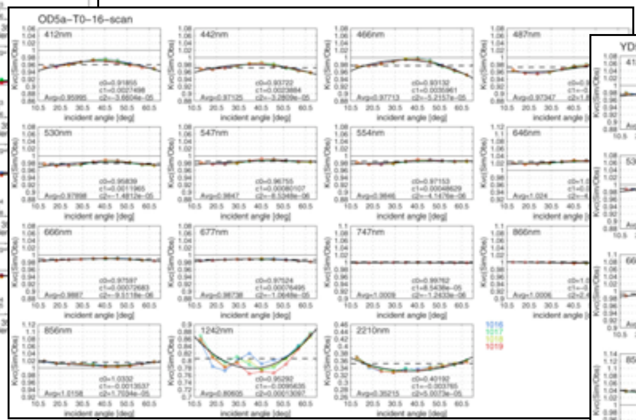
*Apply Kvc for GLI, Terra MODIS and Aqua MODIS*

- Atmospheric correction LUTs (Rayleigh, Solar irradiance, and Aerosol) consider GLI and MODIS channel responses.
- Empirical in-water algorithms for GLI and MODIS are prepared by consistent in-situ data set.
- Satellite $L_{TOA}$ is corrected by the *Kvc* considering $\varphi$ and time (not latitude dependency).

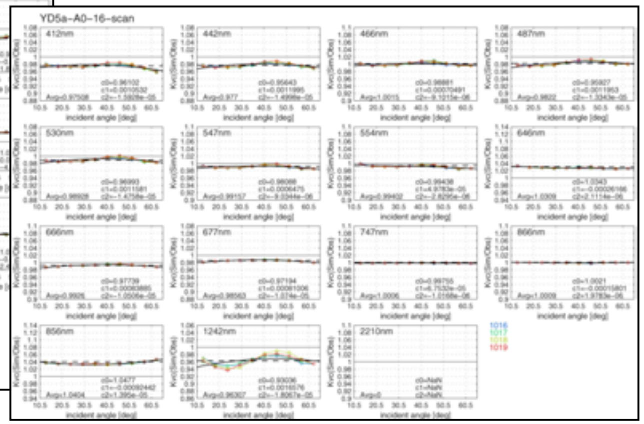


GLI *Kvc*



Terra MODIS *Kvc*

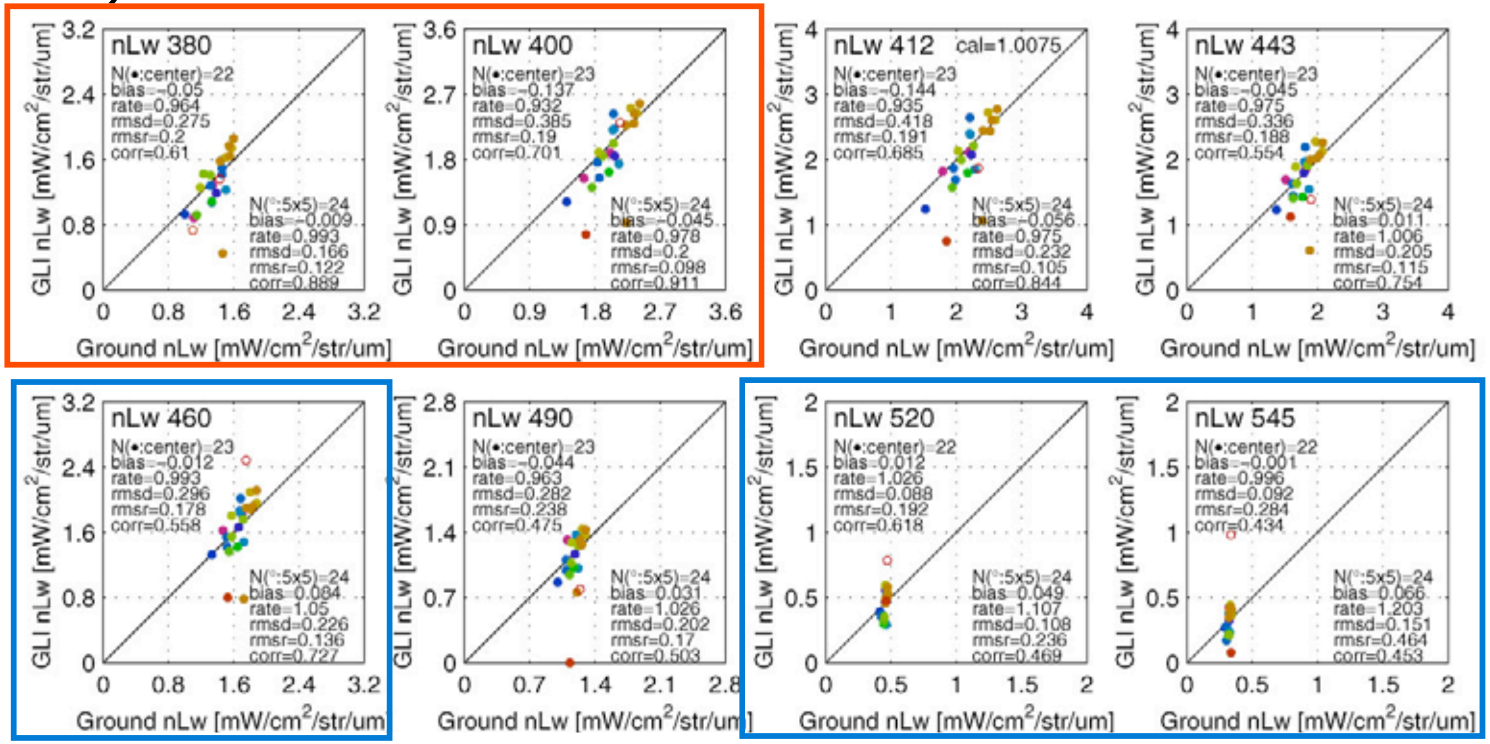


Aqua MODIS *Kvc*

# 5.2 Product tests;

*Confirmation of nLw interpolation*

GLI match-up results show extrapolated nLws (380 and 400nm) and interpolated ones (460, 520, and 545nm) are reasonable as well as ones at same wavelengths with SeaWiFS (412, 443, and 490nm).




Comparison between GLI nLws and MOBY nLws which are weighted for GLI channel responses (provided by Dennis Clark).

# 5.3 Products tests;
*global Tau_a 865nm*

17 Oct. 2003

(1) GLI

(2) Terra MODIS

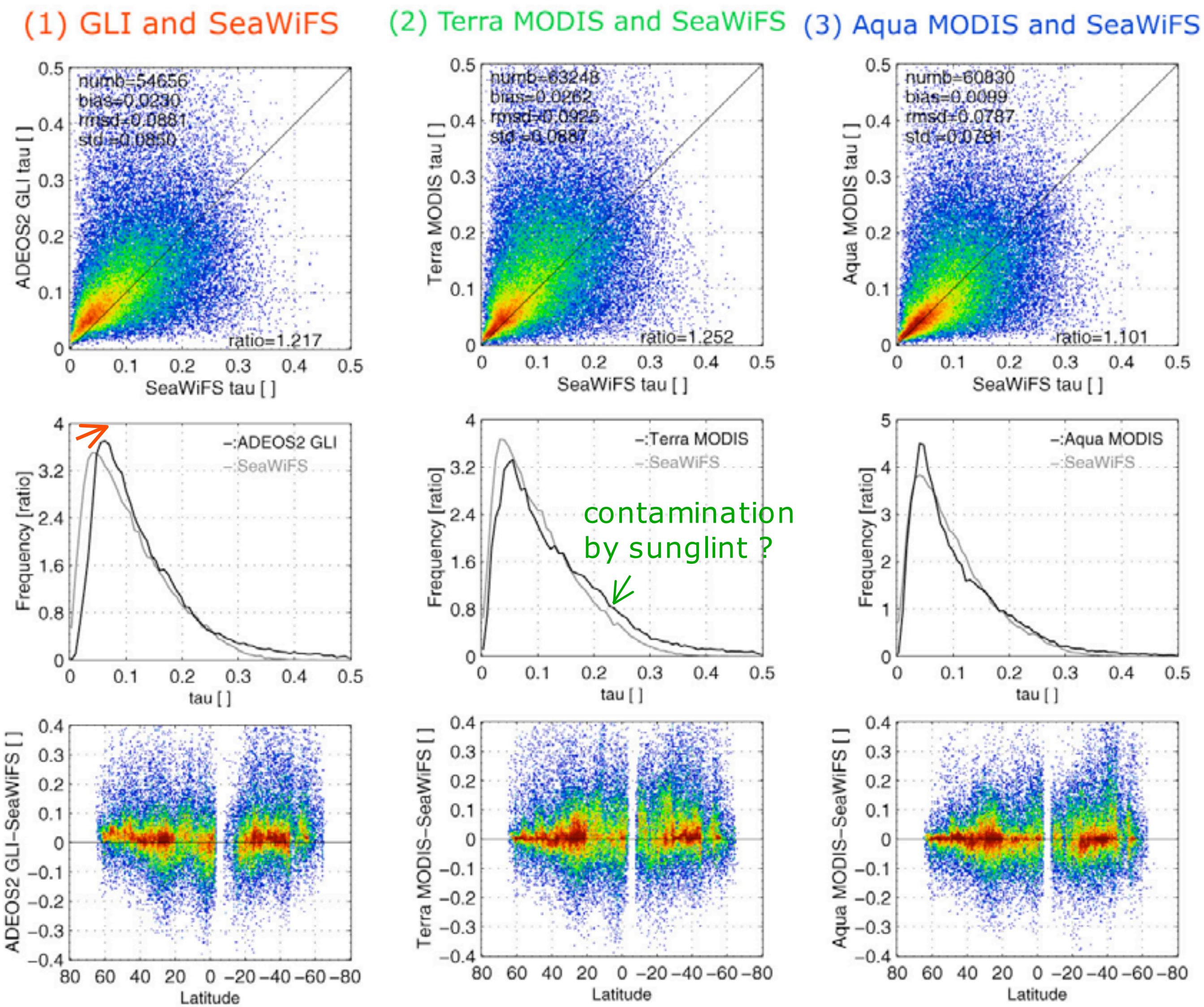
(3) Aqua MODIS

(by this scheme)

*Agree well*

*GLI tau_a is lager than SeaWiFS one.*

*→ Problem in the fixed NIR channels ?*



# 5.4 Products tests;
*global nLw_443*

17 Oct. 2003

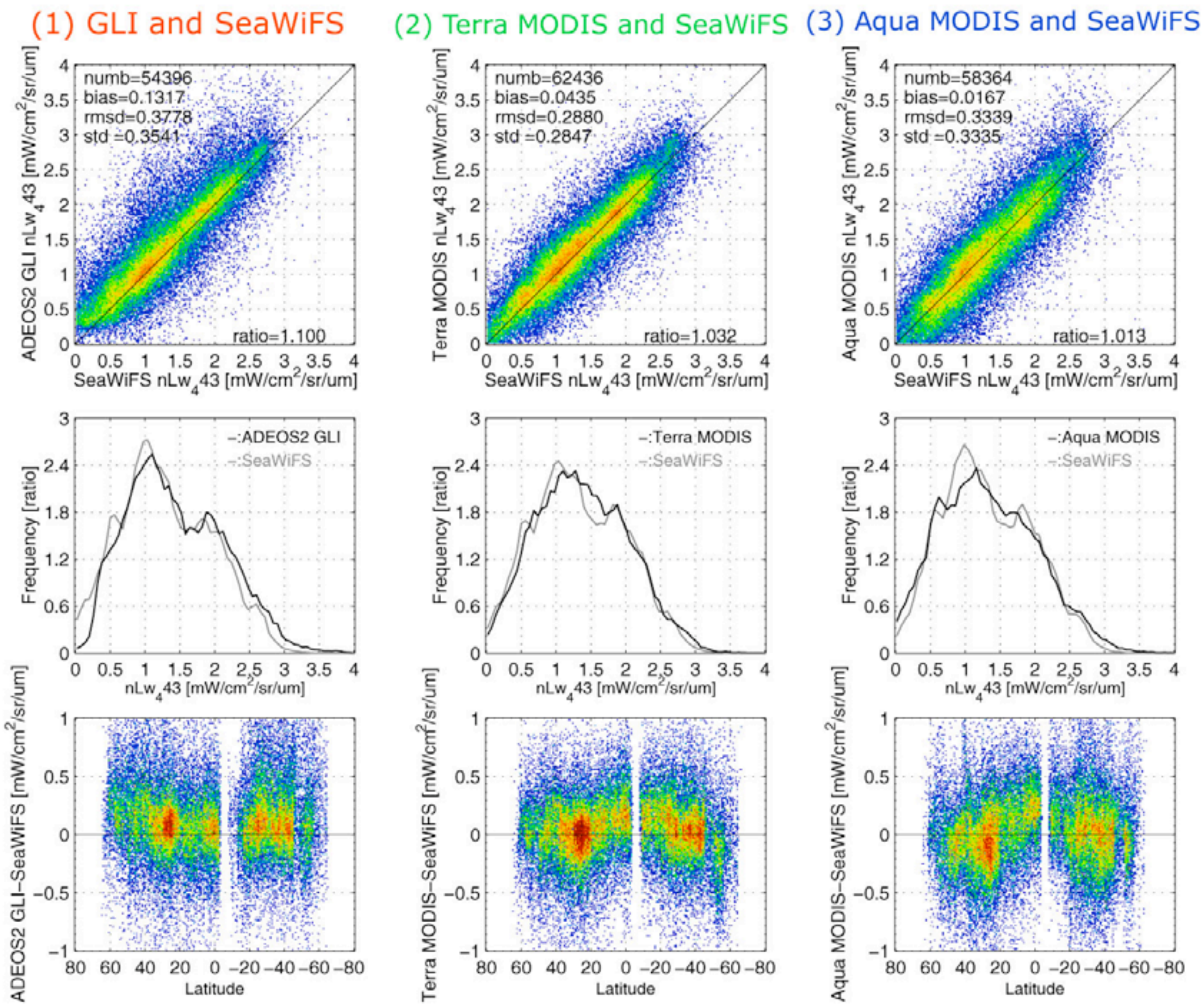
(1) GLI

(2) Terra MODIS

(3) Aqua MODIS

(by this scheme)

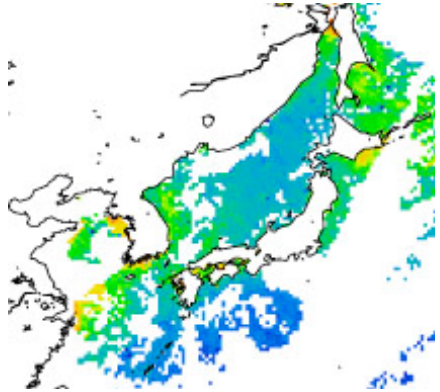
*Agree well*



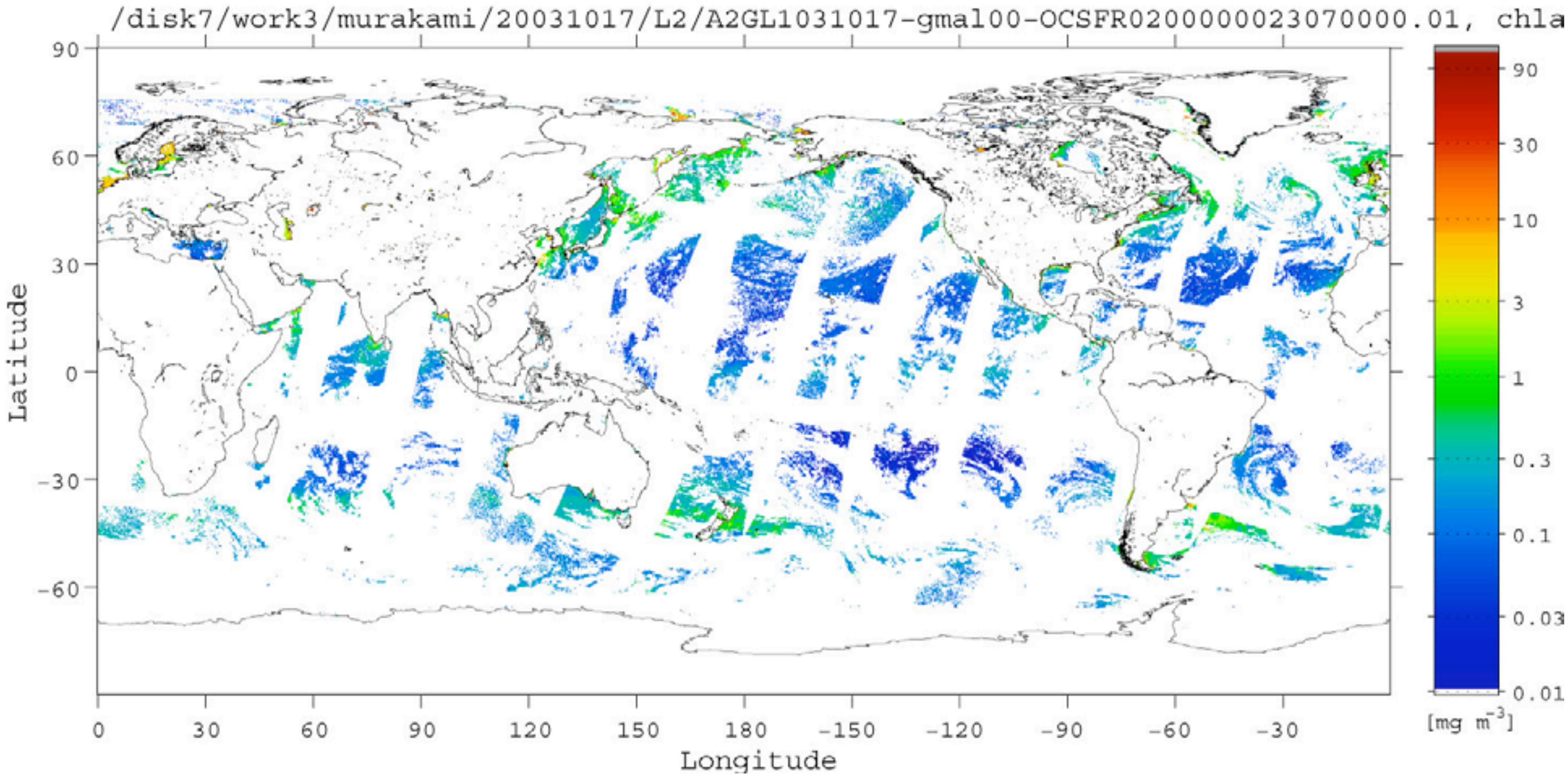
# 5.5 Products tests;

*global chlorophyll-a concentration*

- GLI CHLA 17 Oct. 2003



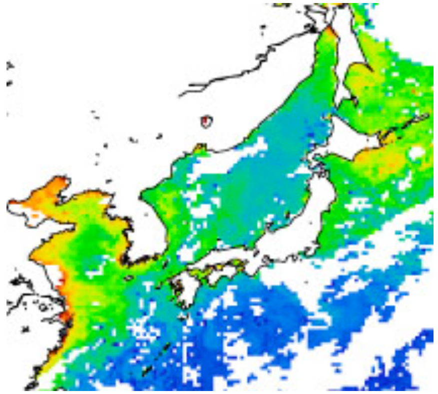
Zoom around Japan



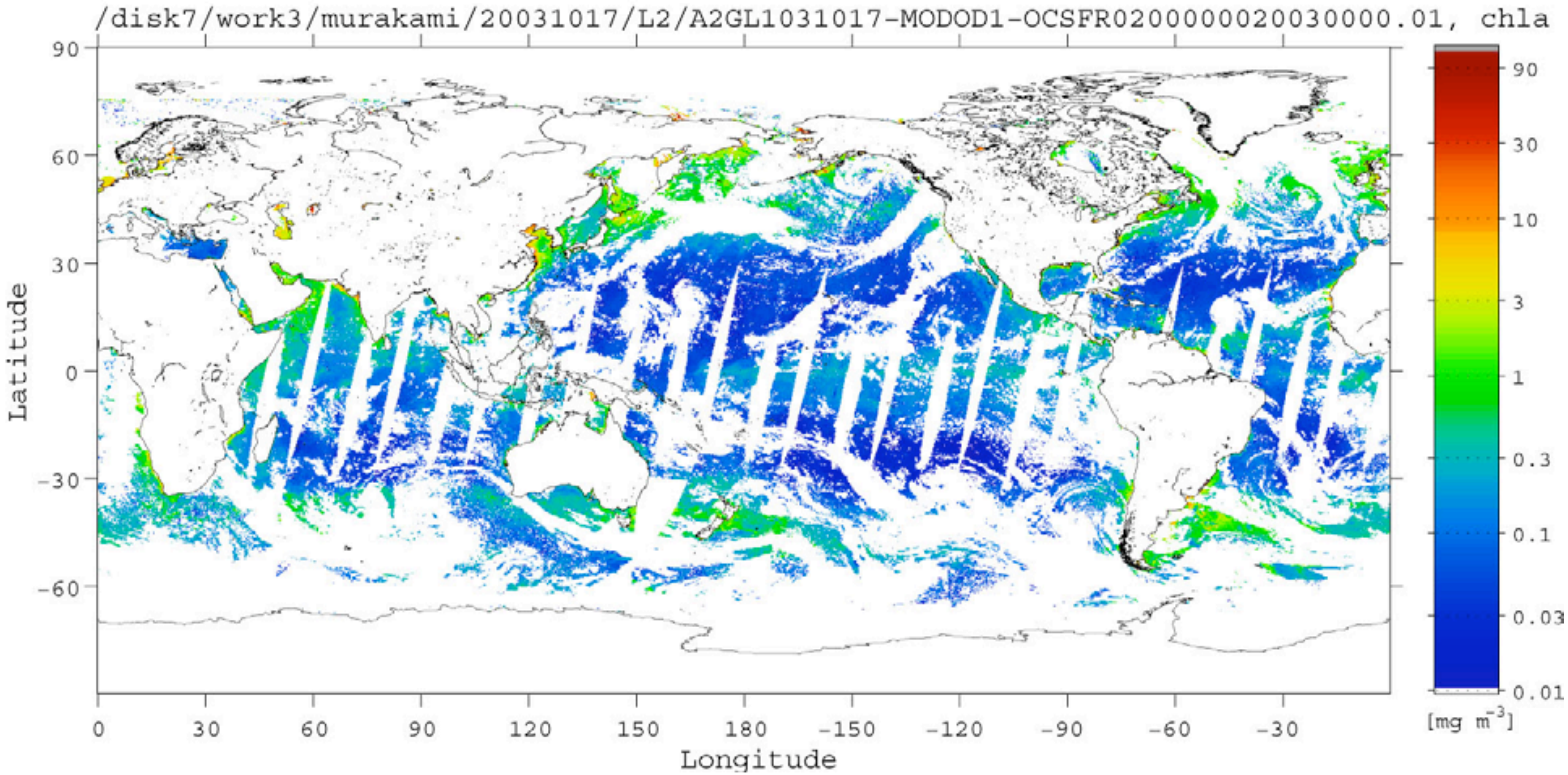
# 5.6 Products tests;

*global chlorophyll-a concentration*

- Terra MODIS 17 Oct. 2003

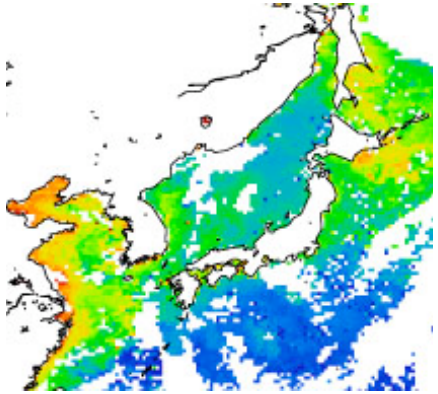


Zoom around Japan

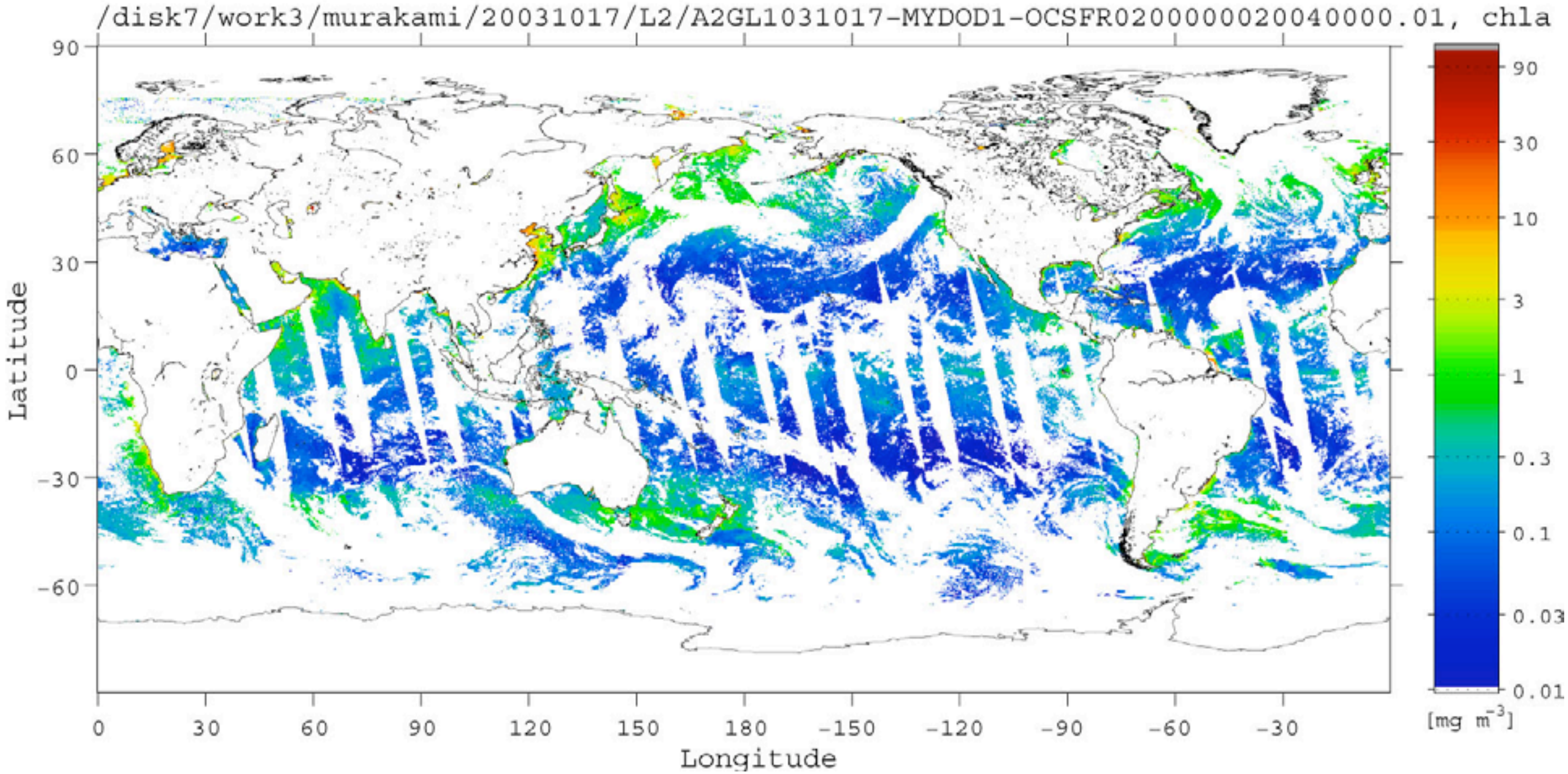


# 5.7 Products tests;
*global chlorophyll-a concentration*

- Aqua MODIS 17 Oct. 2003



Zoom around Japan

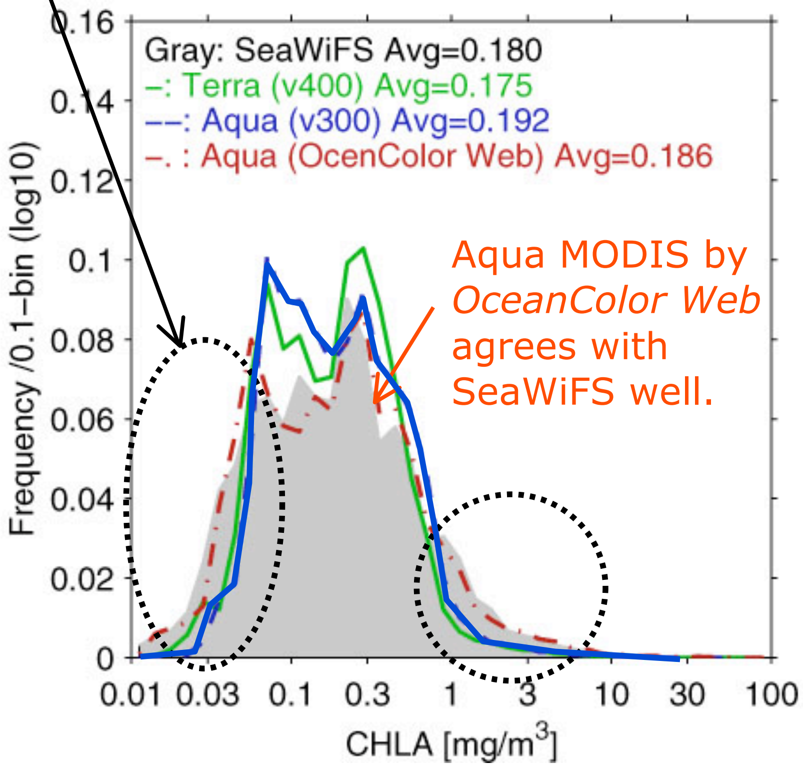


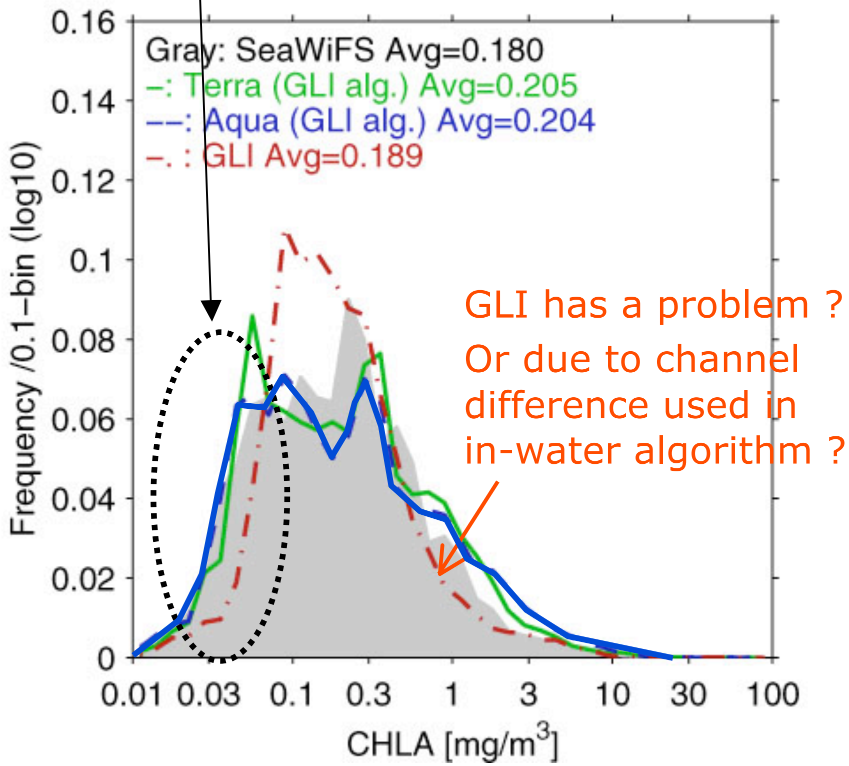
# 5.8 Products tests;

*Comparison with NASA SeaWiFS and MODIS chlorophyll-a products*

In high and low chlorophyll ranges, CHLA by SeaWiFS, Terra MODIS and Aqua MODIS are different.

After this vical, they are agreed well.



# 6. Summary and Conclusions

1) Using global data sets, we could derive vicarious coefficients which have enough accuracy for ocean-color processing. This scheme is available even in the early phase of satellite missions.
2) Large sample number (>100,000) enables to detect several dependencies (scan angle, time, solar position?..) statistically.
3) GLI *Kvc* show,
   - scan-angle dependency and its temporal change for CH01-03.
4) MODIS *Kvc* show,
   - dependency on the sun-glint location (Terra)
   - relatively stable (Aqua)
5) Consistency is improved among ocean-color products by SeaWiFS, GLI, Terra MOIDS and Aqua MODIS by this scheme, but not perfect yet.
6) We should better to know the *Kvc* of two NIR bands (fixed 1.0 in this study) by some independent ways, e.g., in-situ aerosol observation, moon calibration, or in-orbit calibrations.
7) One (or some) well-calibrated sensor(s) should be operated in orbit continuously for the reference.