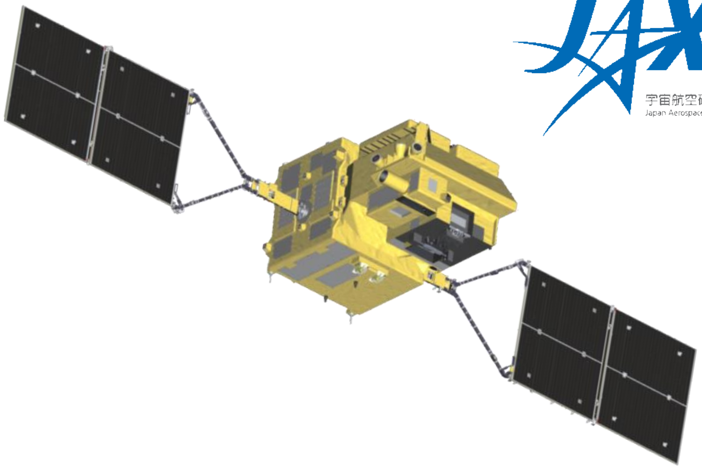


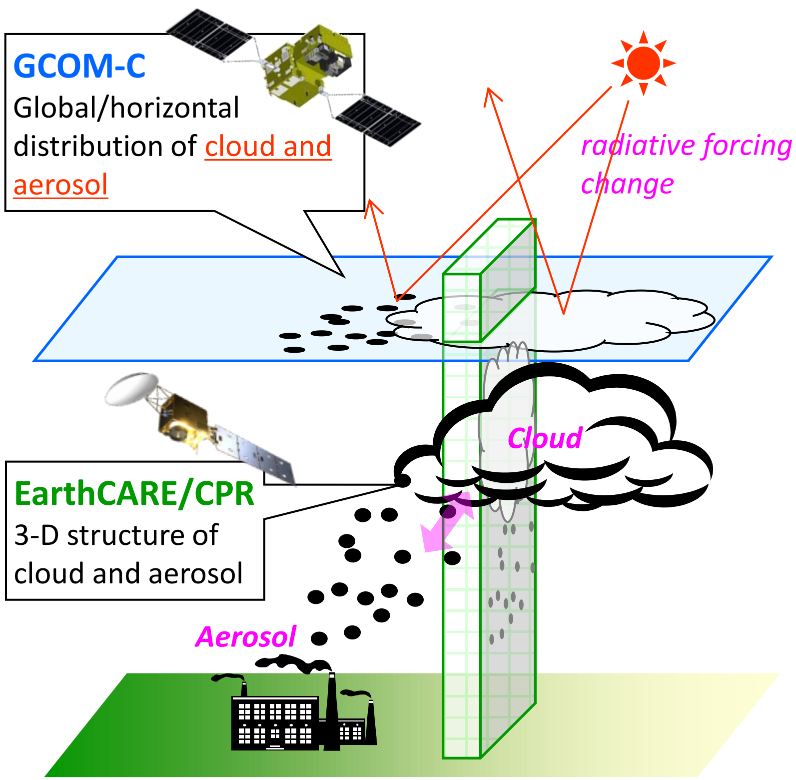
Project update from JAXA: GCOM-C1/SGLI

GCOM-C1: Global Change Observation Mission – Climate, 1st satellite
SGLI: Second-generation GLobal Imager

Hiroshi Murakami
JAXA/EORC
ICAP 2013 Tsukuba Working group meeting
Nov. 6, 2013

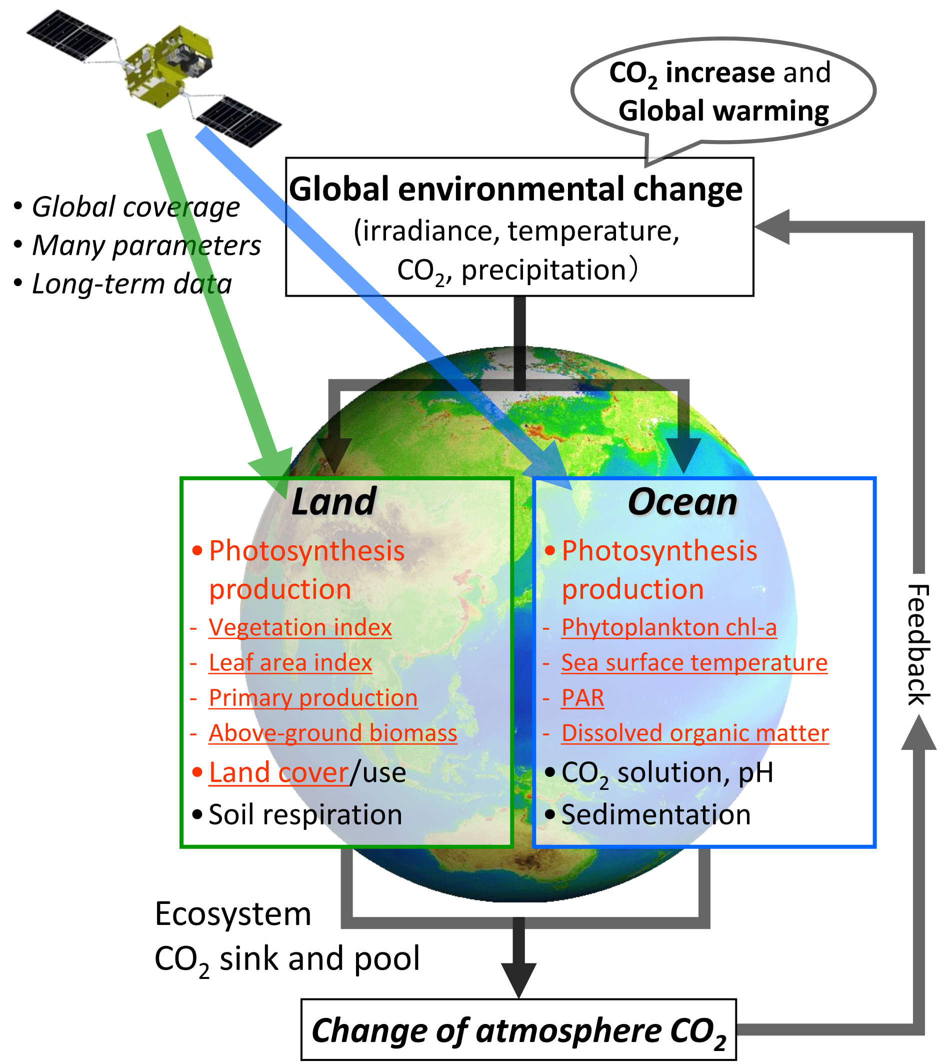
1. GCOM-C Science targets

(1) Radiation budget and Carbon cycle



Monitoring and process knowledge of
cloud and aerosol by GCOM-C & EarthCARE

Evaluation of model outputs and process parameterization



1. GCOM-C Science targets

(2) GCOM-C Observation Products

Common	
Radiance	• TOA radiance (including system geometric correction)

- *Radiation budget by the atmosphere-surface system*
- *Carbon cycle in the Land and Ocean*

Land

Surface reflectance	• Precise geometric correction	
	• Atmospheric corrected reflectance	
Vegetation and carbon cycle	• Vegetation index	
	• Above-ground biomass	ECV
	• Vegetation roughness index	
	• Shadow index	
	• Fraction of Absorbed Photosynthetically available radiation	ECV
	• Leaf area index	ECV
Temp.	• Surface temperature	
Application	Land net primary production	
	Water stress trend	
	Fire detection index	ECV
	Land cover type	ECV
	Land surface albedo	ECV

Atmosphere

Cloud ECV	• Cloud flag/Classification
	• Classified cloud fraction
	• Cloud top temp/height
	• Water cloud optical thickness /effective radius
	• Ice cloud optical thickness
	Water cloud geometrical thickness
Aerosol ECV	• Aerosol over the ocean
	• Land aerosol by near ultra violet
	• Aerosol by Polarization
Radiation budget ECV	Long-wave radiation flux
	Short-wave radiation flux

Blue: standard products

Red: research products

Ocean

Ocean color ECV	• Normalized water leaving radiance	
	• Atmospheric correction parameter	
	• Photosynthetically available radiation	
	Euphotic zone depth	
In-water	• Chlorophyll-a conc.	
	• Suspended solid conc.	
	• Colored dissolved organic matter	
In-water	Inherent optical properties	
Temp.	• Sea surface temp.	ECV
Application	Ocean net primary productivity	
	Phytoplankton functional type	
	Redtide	
	multi sensor merged ocean color	
	multi sensor merged SST	

Cryosphere

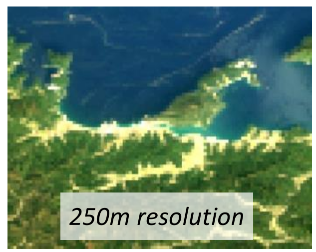
Area/ distribution	• Snow and Ice covered area	ECV
	• Okhotsk sea-ice distribution	
	Snow and ice classification	
	Snow covered area in forest and mountain	
Surface properties	• Snow and ice surface Temperature	
	• Snow grain size of shallow layer	
	Snow grain size of subsurface layer	
	Snow grain size of top layer	
	Snow and ice albedo	ECV
	Snow impurity	
	Ice sheet surface roughness	
Boundary	Ice sheet boundary monitoring	ECV

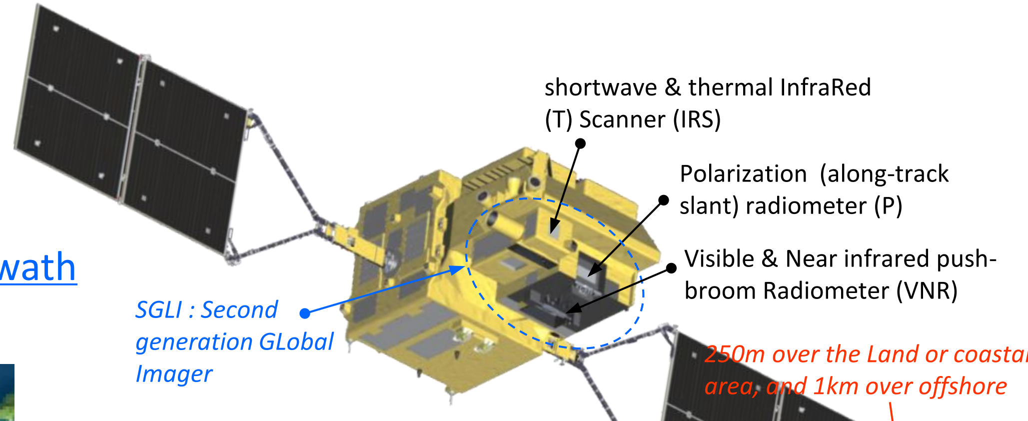
2. GCOM-C1/ SGLI

Improvement of the land, coastal, and aerosol observations

✓ 250m spatial resolution with 1150~1400km swath

✓ Polarization/along-track slant view





GCOM-C SGLI characteristics (Current baseline)	
Orbit	Sun-synchronous (descending local time: 10:30), Altitude: 798km, Inclination: 98.6deg
Launch Date	**JFY 2016 (TBD)**
Mission Life	5 years (3 satellites; total 13 years)
Scan	Push-broom electric scan (VNR: VN & P) Wisk-broom mechanical scan (IRS: SW & T)
Scan width	1150km cross track (VNR: VN & P) 1400km cross track (IRS: SW & T)
Digitalization	12bit
Polarization	3 polarization angles for P
Along track tilt	Nadir for VN, SW and T, & +/-45 deg for P
On-board calibration	VN: Solar diffuser, Internal lamp (LED, halogen), Lunar by pitch maneuvers (~once/month), and dark current by masked pixels and nighttime obs. SW: Solar diffuser, Internal lamp, Lunar, and dark current by deep space window TIR: Black body and dark current by deep space window All: Electric calibration

SGLI channels

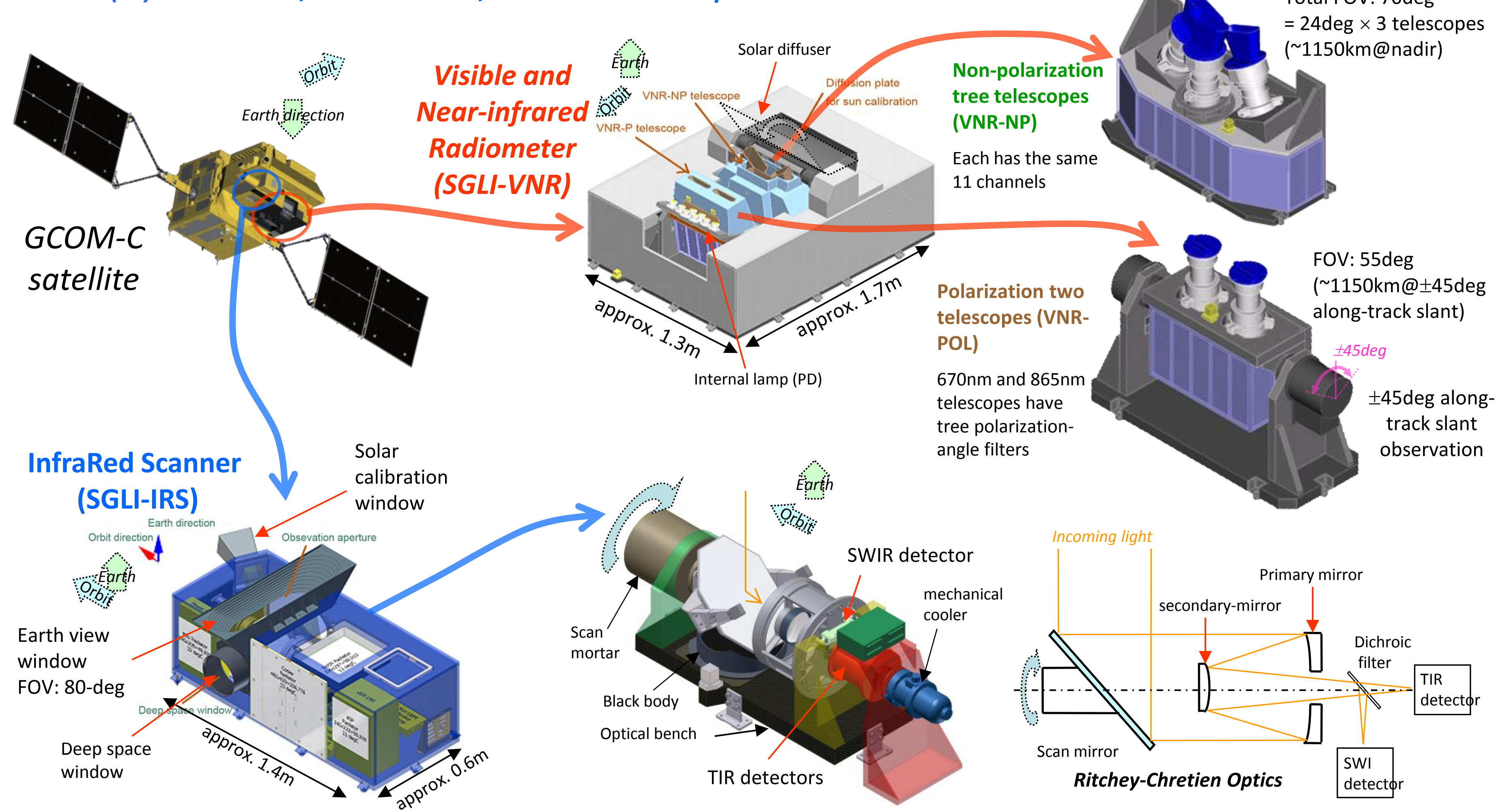
CH	λ	$\Delta\lambda$	L_{std}	L_{max}	SNR at Lstd	IFOV
	VN, P, SW: nm T: μm		VN, P: W/m²/sr/μm T: Kelvin		VN, P, SW: - T: NEΔT	m
VN1	380	10	60	210	250	250
VN2	412	10	75	250	400	250
VN3	443	10	64	400	300	250
VN4	490	10	53	120	400	250
VN5	530	20	41	350	250	250
VN6	565	20	33	90	400	250
VN7	673.5	20	23	62	400	250
VN8	673.5	20	25	210	250	250
VN9	763	12	40	350	1200(@1km)	250
VN10	868.5	20	8	30	400	250
VN11	868.5	20	30	300	200	250
POL1	673.5	20	25	250	250	1000
POL2	868.5	20	30	300	250	1000
SW1	1050	20	57	248	500	1000
SW2	1380	20	8	103	150	1000
SW3	1630	200	3	50	57	250
SW4	2210	50	1.9	20	211	1000
TIR1	10.8	0.7	300	340	0.2	500/250
TIR2	12.0	0.7	300	340	0.2	500/250

Multi-angle obs. for 674nm and 869nm

250m-mode possibility

2. GCOM-C1/ SGLI

(2) VNR-NP, VNR-POL, and IRS components

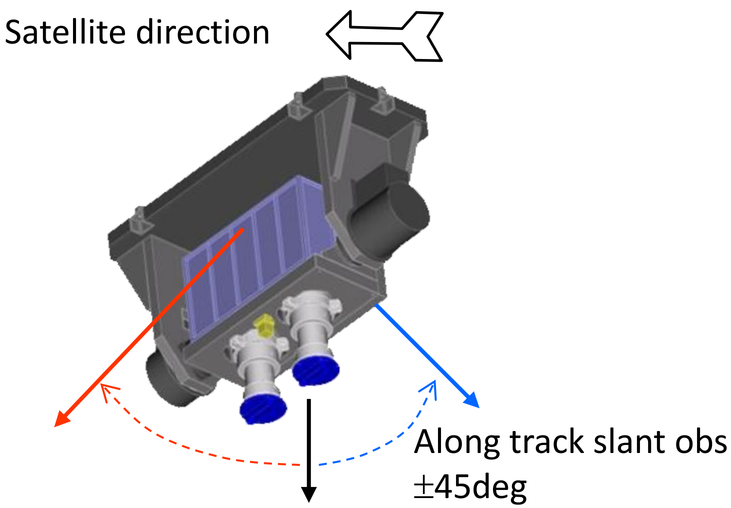


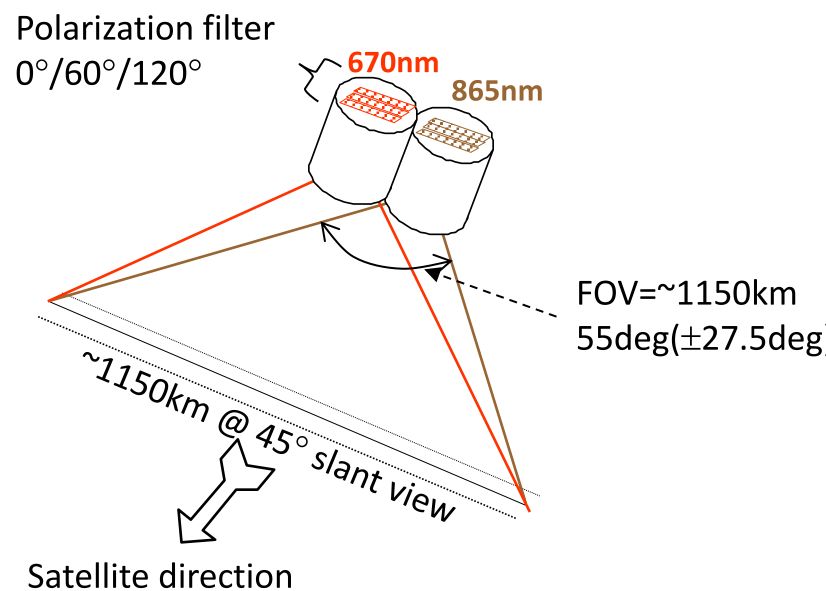
Engineering Model (EM) development & test

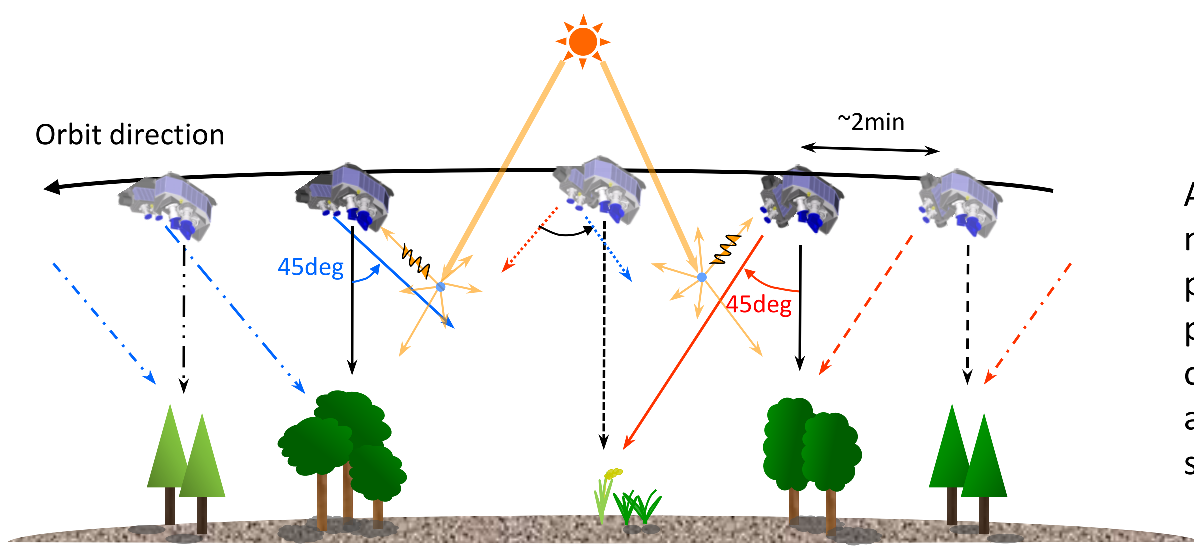
- Filters manufacturing: Spectral response of filters (uniformity of λc: 0.5-1.0nm in FOV, characterized by 0.1nm)
- CCD (EM) manufacturing: completed; Pre-Flight Model manufacturing has been started
- Stray Light : Telescope test with the CCD; Numerical correction method study with convolution technique
- Calibration : Integrating sphere calibration with national standards

2. GCOM-C1/ SGLI

(3) SGLI Polarimetry

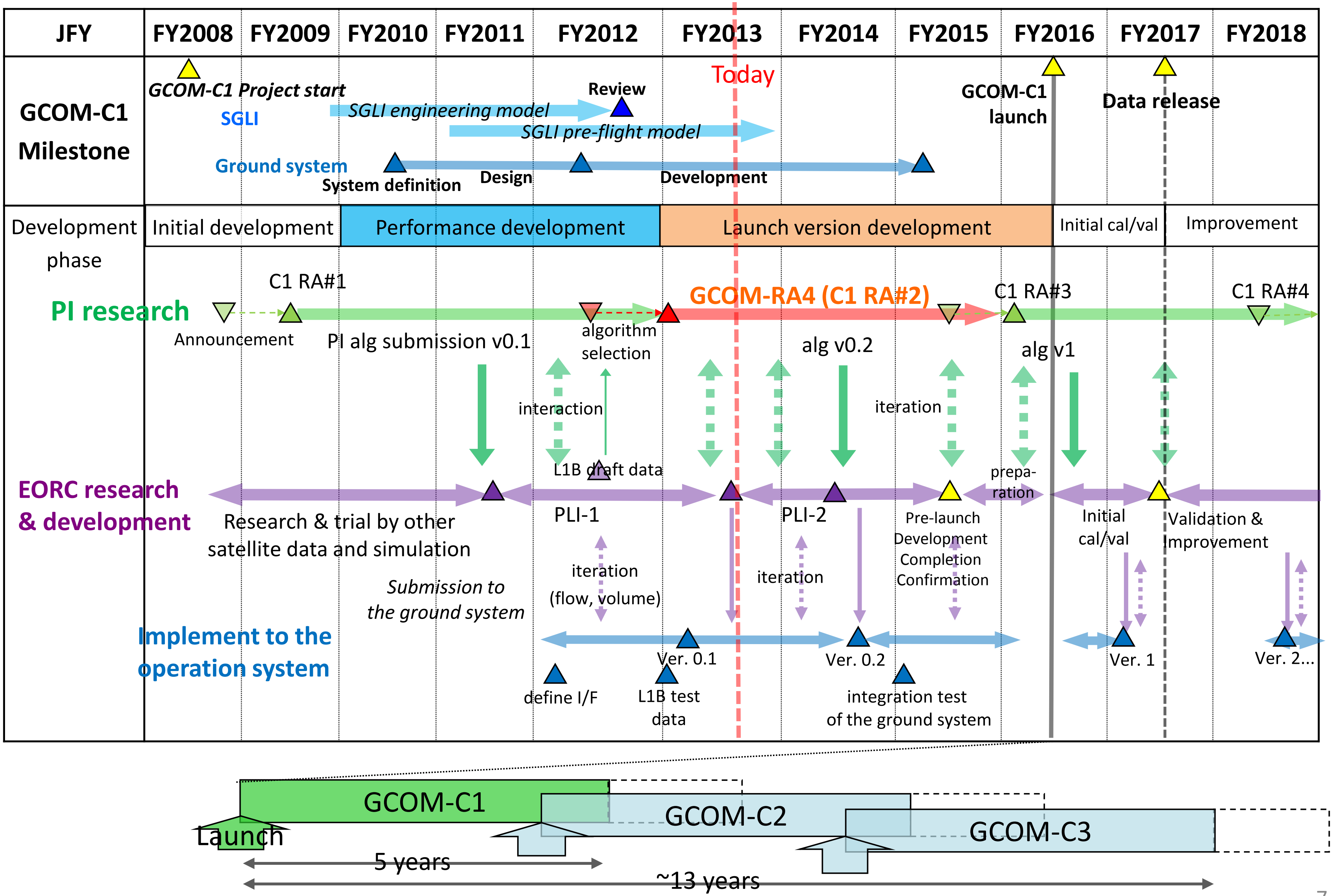






Along-track ±45deg modes will be planned for polarization observation of the atmospheric scattering

3. Status of GCOM-C1 project



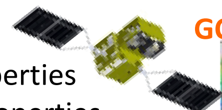
Framework of the atmosphere area activities

Improvement of aerosol and aerosol products through polarization, NUV, and wide-swath observations, and contribution to the estimation of radiative forcing through collaboration with in-situ observations and cloud-aerosol and climate models

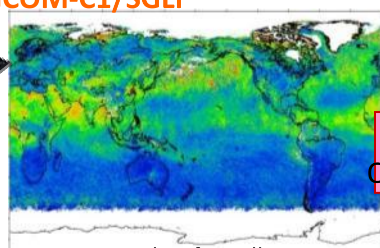
Satellite

Tokyo Univ. (AORI), Tokai Univ., Kinki Univ, MRI, Nara W. Univ., Lille Univ. JAXA, etc.

SGLI
- Cloud properties
- Aerosol properties
- Radiation budget

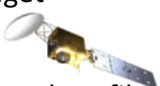


GCOM-C1/SGLI



An example of satellite AOT

EarthCARE
- Cloud and aerosol profiles



Himawari-8/9
- Cloud and aerosol profiles

AMSR2
- Column water vapor
- Cloud liquid water

Other satelites..

Products
Optical process

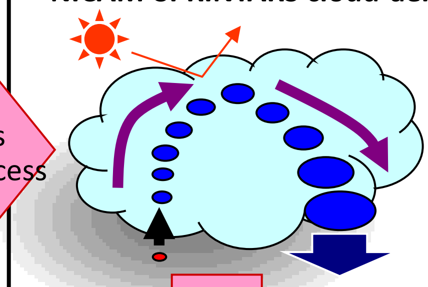
Comparison
Validation
Constrain?

Comparison
Validation

Model

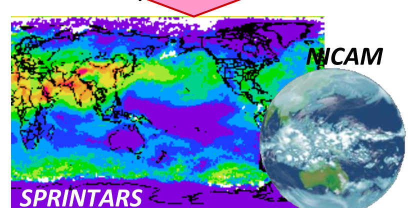
Tokyo Univ. (AORI), MRI

NICAM-SPRINTARS cloud-aerosol model



Model process improvement
- Cloud growth and precipitation
- Aerosol transportation
- Optical properties

Accuracy improvement



cited from AORI HP

Model outputs
- Cloud properties & distribution
- Aerosol properties & distribution
- Radiative forcing

Scheme integration

Climate models
- Climate change prediction and verification

In situ

- Cloud properties
- Cloud liquid water
- Aerosol properties
- Radiance (spectral, direct..)
- Reflectance

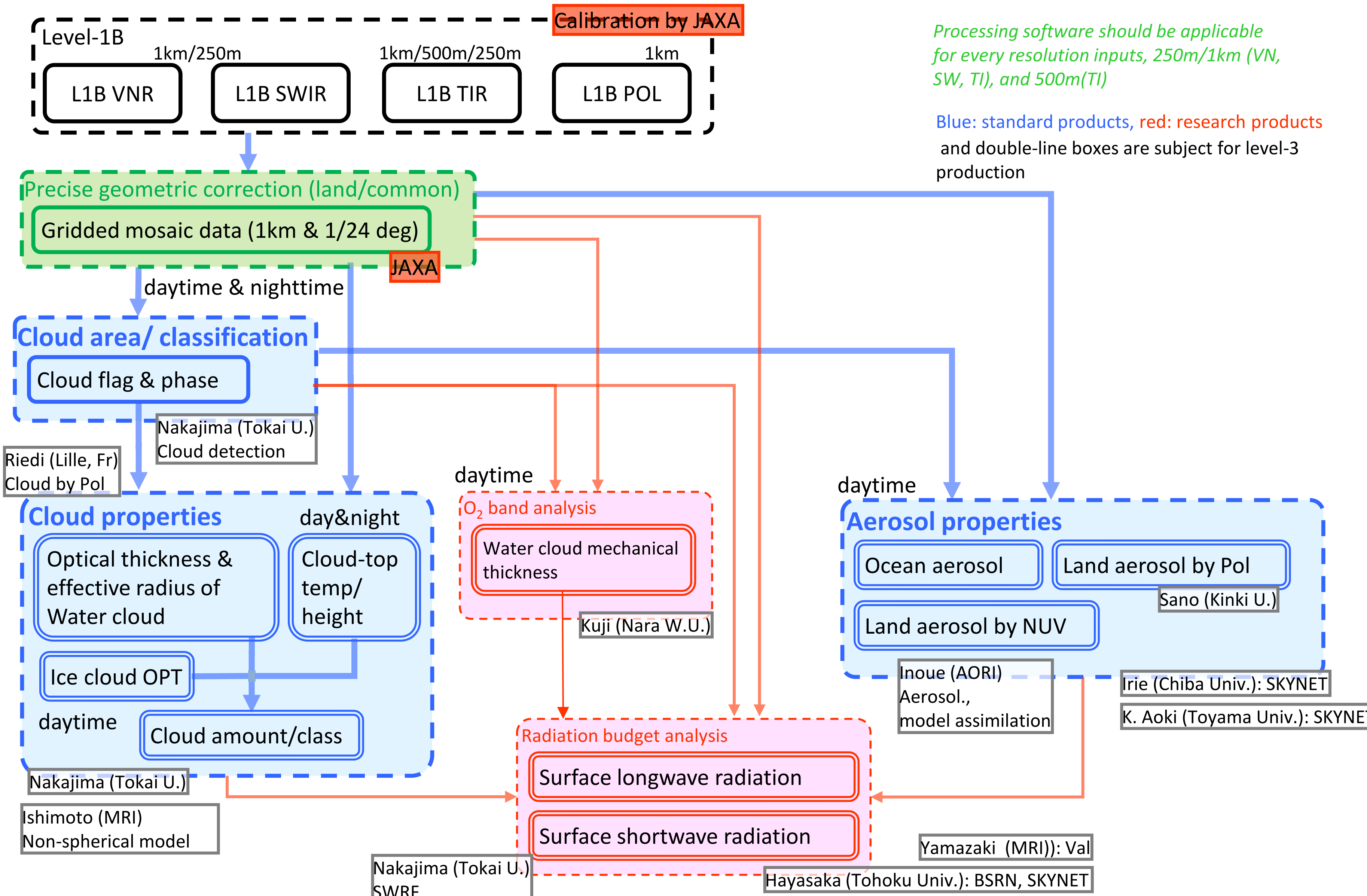
cited from SKYNET HP

Comparison
Validation

SKYNET (Chiba, Tokyo, Toyama, Tohoku Univ...), AERONET (Kinki Univ...), MRI, etc.

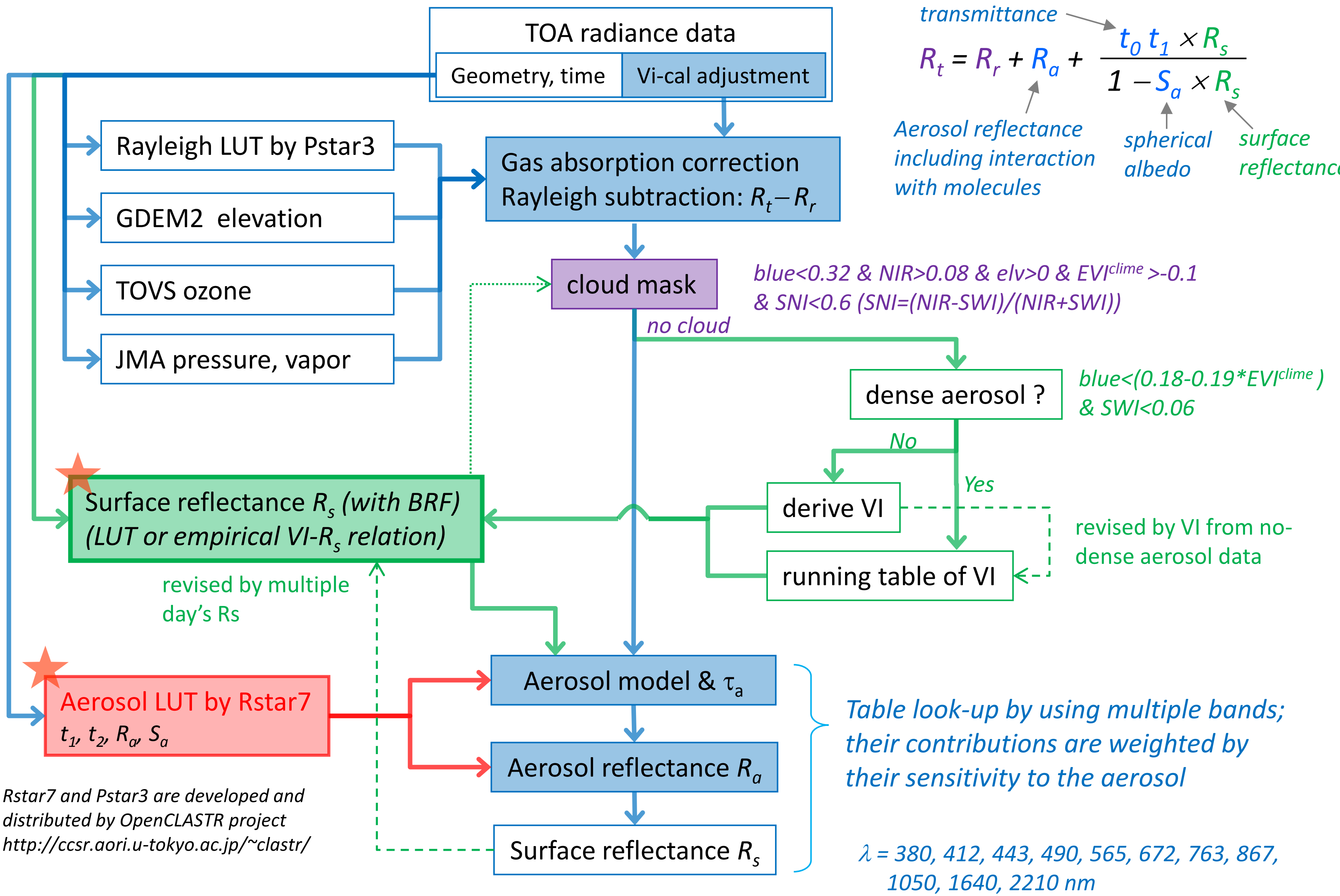
4. GCOM-C1 aerosol estimation

(1) GCOM-C1 data processing flow (Atmosphere)



4. GCOM-C1 aerosol estimation

(2) An example of flow of the traditional algorithm



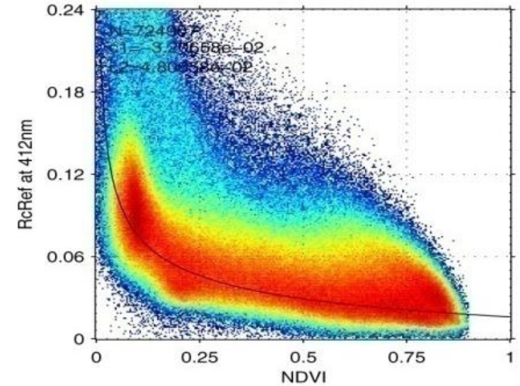
Rstar7 and Pstar3 are developed and distributed by OpenCLASTR project http://ccsr.aori.u-tokyo.ac.jp/~clastr/

4. GCOM-C1 aerosol estimation

(3) Pre-estimation of surface reflectance

Estimation of near UV~blue (and red) reflectance by simultaneous NIR or SWIR

- ✓ Spatial/temporal change of vegetation spectrum
- ✓ Local soil optical properties..
- ✓ Consideration of BRDF



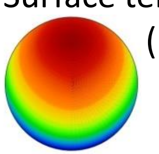
NDVI-412nm relation (MODIS global)

Or prepare static LUT?: e.g., $R(\theta_0, \theta_1, \varphi) = k_0 + k_1 \times F_1(\theta_0, \theta_1, \varphi) + k_2 \times F_2(\theta_0, \theta_1, \varphi)$

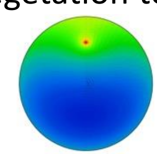
412nm 646nm 857nm 2114nm

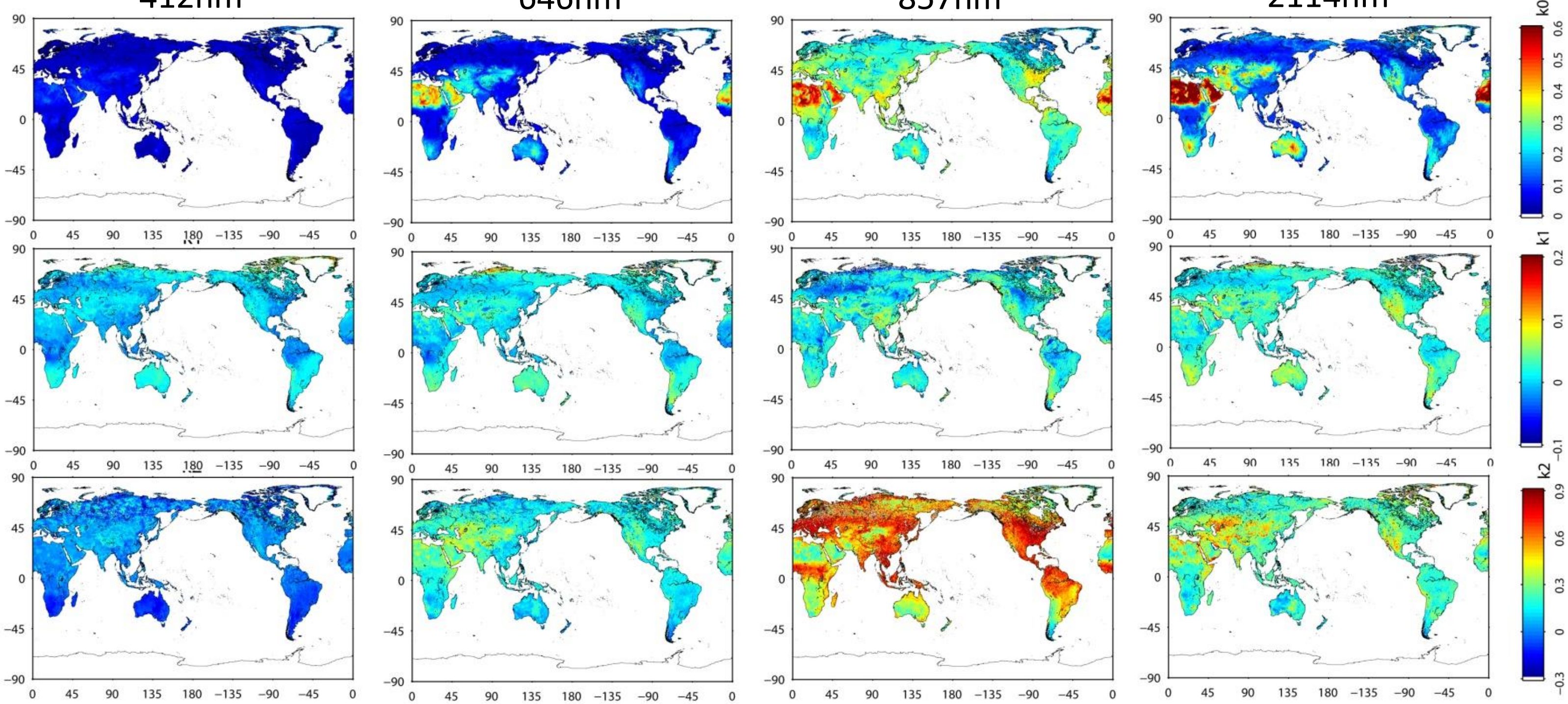
Nadir reflectance (k_0)

Surface term (k_1)



Vegetation term (k_2)

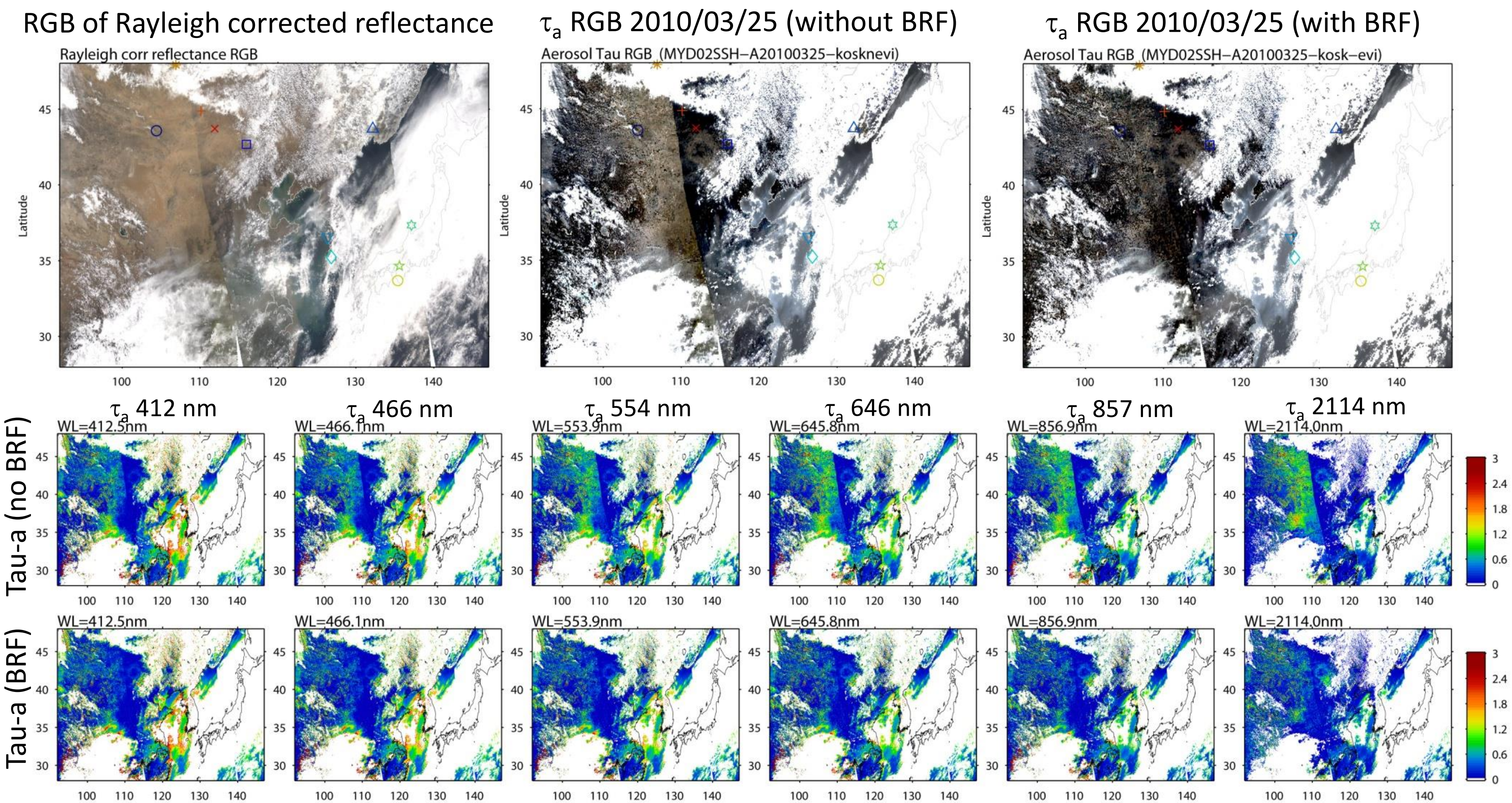




BRDF kernels by Maignan et al., 2004

July mean of MODIS 2003-2010

Influence of land surface BRDF

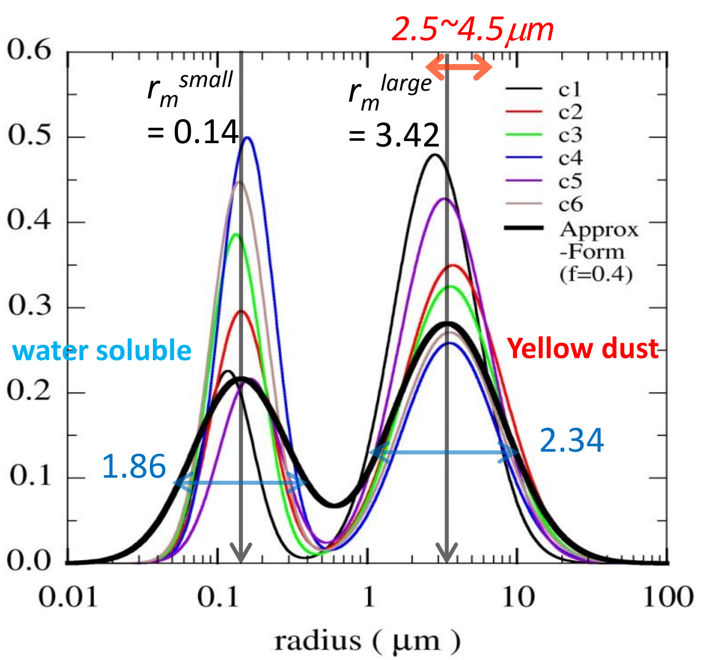


- Gap of τ_a on the neighboring path boundary is corrected by the land surface BRDF
- The BRDF effect is small in 412nm-443nm and large in 554-2114nm

4. GCOM-C1 aerosol estimation

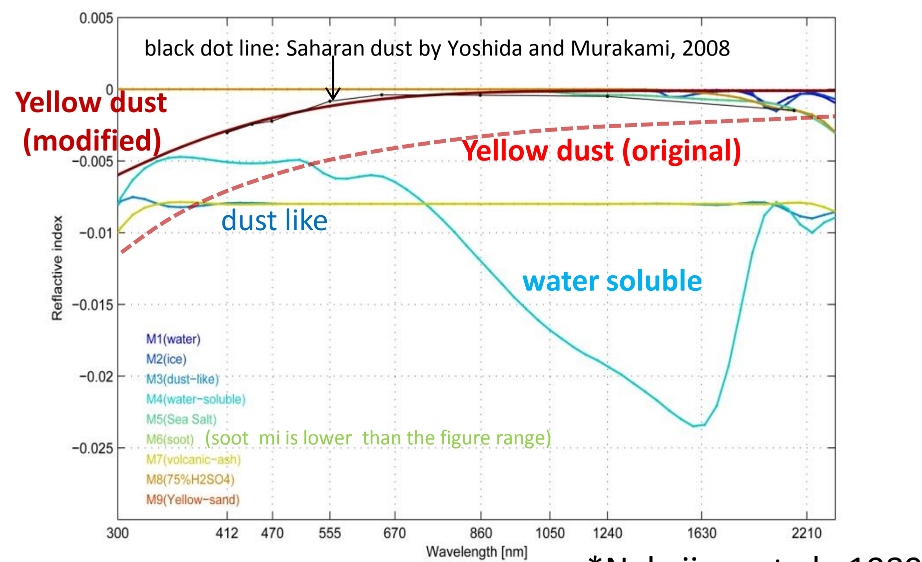
(4) Aerosol models (size distribution and absorption)

Size distribution



Cited from *"Report about modeling of the aerosol size distribution"* Makiko Nakata, Itaru Sano, and Sonoyo Mukai, Kinki Univ., 20 May 2011, *in Japanese*

Imaginary part of the refractive index (m_i)



*Nakajima et al., 1989

Other parameters:

- *Vertical distribution,*
- *Non-spherical parameter (e.g., x0, G, r)*
- *Density (to connect model g/m³)*

Current discussions:

- How to set the candidate aerosol models
  - ✓ Climatology from AERONET and SKYNET
  - ✓ Revision by new in-situ measurement results
  - ✓ Local area dependence?
- Consistency between the aerosol transport model and the satellite aerosol algorithms

Influence of the size distribution & refractive index

Following four cases were tested in the East Asia (by MODIS; val by AERONET)

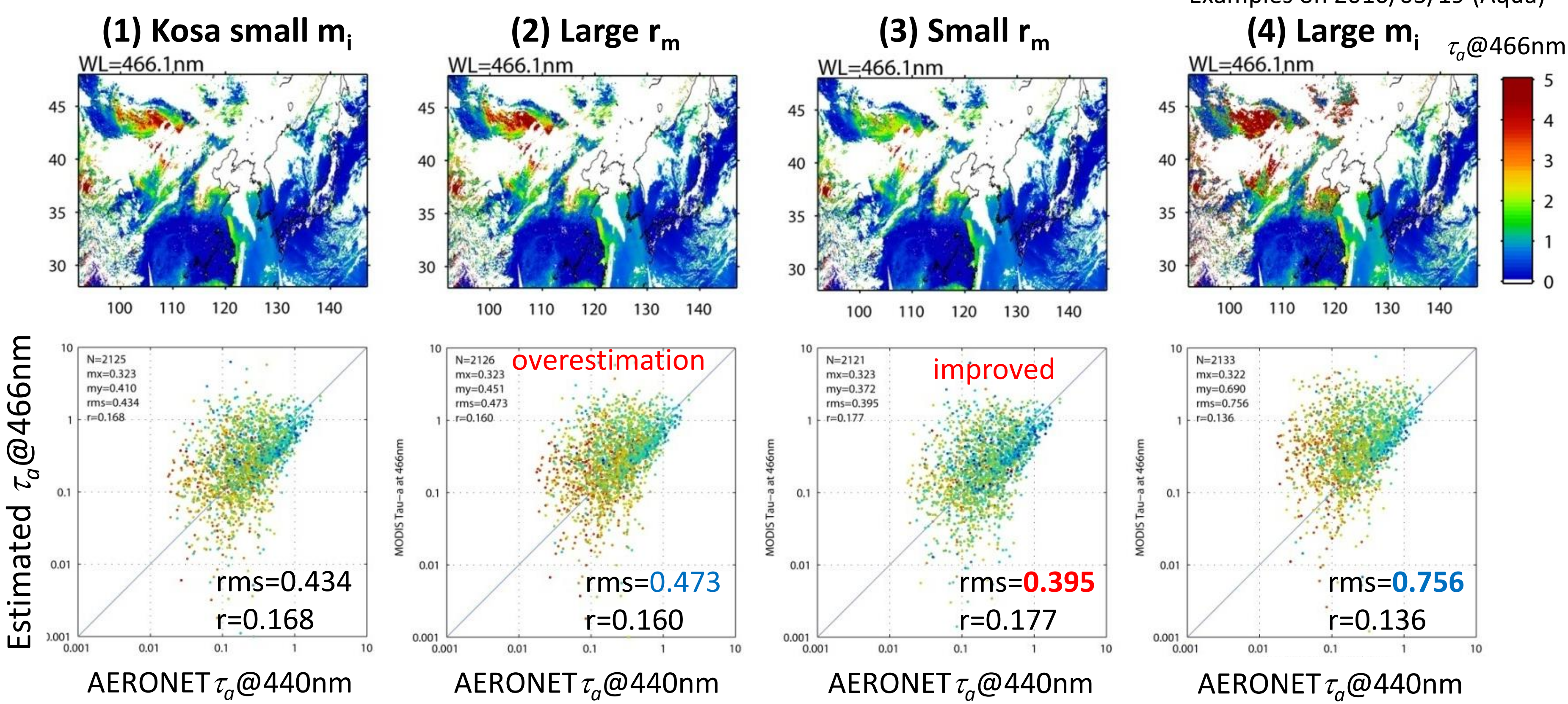
(1) Large particle m_i^{large} is changed by a half from the Rstar yellow sand model* (baseline)

(2) mode radius of r_m^{large} :3.42→4.5μm

(3) mode radius of r_m^{large} :3.42→2.5μm

(4) Large particle m_i is set by the Rstar yellow sand model*

Examples on 2010/03/19 (Aqua)



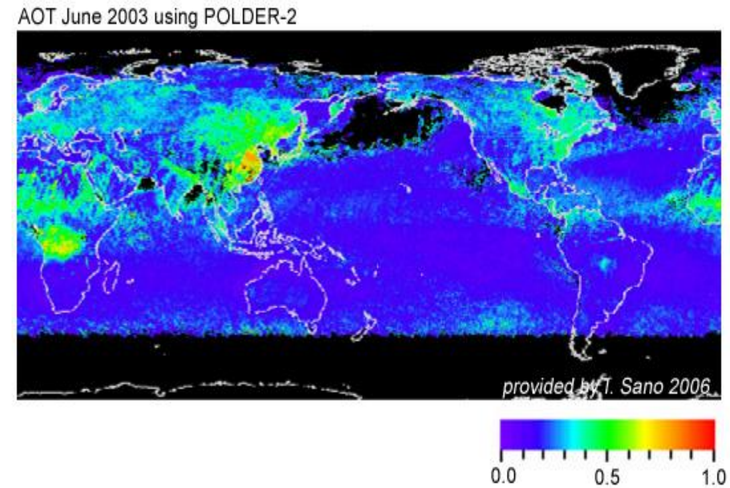
Scatter plots of match-up samples in 2002-2011 (Aqua)

4. GCOM-C1 aerosol estimation

(5) Use of SGLI polarization observation

POLDER experience

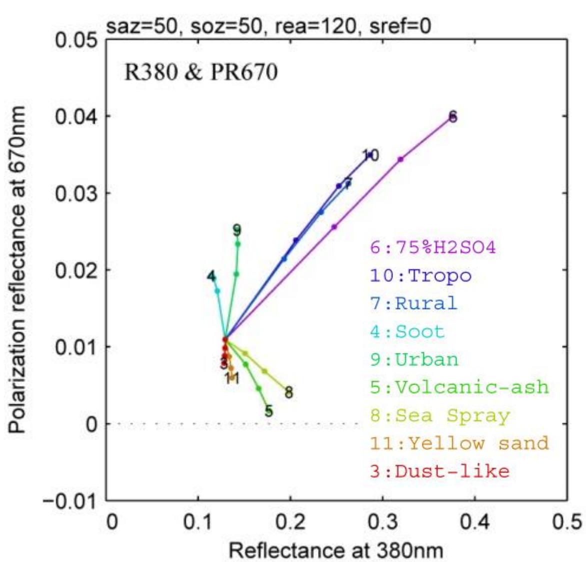
- Experience of satellite POL data analysis
- POLDER BPDF data base (function of land cover classification and vegetation index) has been provided by Dr. Bréon under JAXA/SGLI and CNES/POLDER/3MI collaboration



Global aerosol optical thickness in June 2003 using POLDER-2 polarization reflectance (provided by I. Sano, Kinki Univ.)

Difference of SGLI from POLDER

- 1-km resolution
  - ✓ Cloud contamination will be improved than POLDER
  - ✓ 1-km scale land cover and geographical influence should be confirmed (applicability of the POLDER ground BPDF)
  - ✓ Combined use of the nadir-slant views for aerosol type estimation (influence of IFOV, registration..)
- Single viewing angle (+45° or -45° along track)
  - ✓ Single scattering angle condition (mostly in 60~120 degrees)
  - ✓ Sunglint over the ocean (and flood land?)



5. Validation plan

1. Match-up analysis with SKYNET, AERONET and other observation groups
2. Uncertainty assessment@pixel is required for model assimilation
   i. Empirical approach
      A) Validation @ASRVN, AERONET-OC, in-situ observation champagne (TBD)..
      B) AERONET comparison in each condition
   ii. Theoretical analysis
      A) Error of satellite sensor calibration
         - Calibration from pre-launch to on-orbit, and vicarious adjustment
      B) Error dependency of the algorithm and observation condition
         - Surface reflectance error relating with its brightness, directionality and variability (vegetation)
         - Locality of the aerosol properties (size and absorption, with humidity?)
         - Error sensitivity on the satellite & solar geometries (scattering angle)
         - Contamination by clouds, shadow, snow, and sunglint

Area	Group	Product	Release threshold	Standard accuracy	Target accuracy
Atmosphere	Cloud	Cloud flag/Classification	10% (with whole-sky camera)	Incl. below cloud amount	Incl. below cloud amount
		Classified cloud fraction	20% (on solar irradiance)[*8]	15%(on solar irradiance)[*8]	10%(on solar irradiance)[*8]
		Cloud top temp/height	1K[*9]	3K/2km (top temp/height)[*10]	1.5K/1km (temp/height)[*10]
		Water cloud OT/effective radius	10%/30% (CloudOT/radius) [*11]	100% (as cloud liquid water[*13])	50%[*12] / 20%[*13]
		Ice cloud optical thickness	30%[*11]	70%[*13]	20%[*13]
	aerosol	Aerosol over the ocean	0.1(Monthly τa_670,865)[*14]	0.1(scene τa_670,865)[*14]	0.05(scene τa_670,865)
		Land aerosol by near ultra violet	0.15(Monthly τa_380)[*14]	0.15(scene τa_380)[*14]	0.1(scene τa_380)
		Aerosol by Polarization	0.15(Monthlyτa_670,865)[*14]	0.15(scene τa_670,865)[*14]	0.1(scene τa_670,865)

*8: Comparison with in-situ observation on monthly 0.1-degree
*9: Vicarious val. on sea surface and comparison with objective analysis data
*10: Inter comparison with airplane remote sensing on water clouds of middle optical thickness
*11: Release threshold is defined by vicarious val with other satellite data (e.g., global monthly statistics in the mid-low latitudes)
*12: Comparison with cloud liquid water by in-situ microwave radiometer
*13: Comparison with optical thickness by sky-radiometer (the difference can be large due to time-space inconsistence and large error of the ground measurements)
*14: Estimated by experience of aerosol products by GLI and POLDER

6. Summary

- ***GCOM-C targets***
  - Long-term observations of the climate system (the radiation budget and carbon cycle)
- ***GCOM-C/SGLI characteristics***
  - 250-m resolution and 1150-km (1400-km) swath for the land and coast observations
  - Near-UV (380nm) and polarization observation for the land aerosol estimation
  - Two-angle × two channel observations for the biomass and land cover classification
  - (Multiple calibration functions: solar diffuser, LED, Moon, and vical)
- ***Schedule***
  - Satellite, sensor, ground system, and algorithm are developing for the launch in 2016; Manufacturing of the SGLI Pre-Flight Model is starting
  - GCOM-C PI team has been organized since summer 2009; Currently, the second research period JFY2013-2015 is ongoing
- ***Science challenges*** (about the aerosol product)
  - Candidate aerosol models (size distribution and refractive index)
  - Surface BRF modeling (with canopy radiative transfer model by GCOM-C1 land group)
  - Error range estimation and flagging for the model assimilation
- ***Others***
  - L1, 2, and 3 products will be released to the public one year after the launch
  - NRT data flow
  - GCOM products will be free of charge for internet acquisition