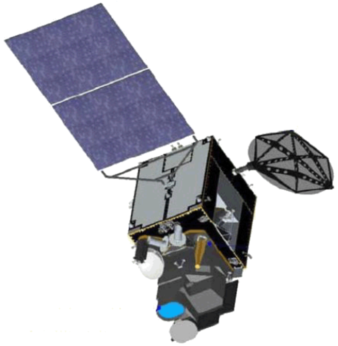
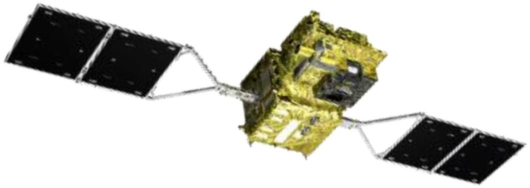
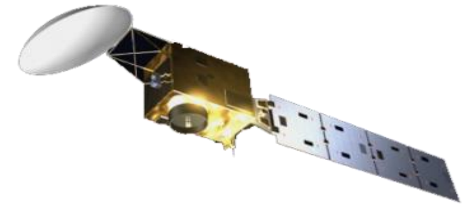





JAXA aerosol observation missions

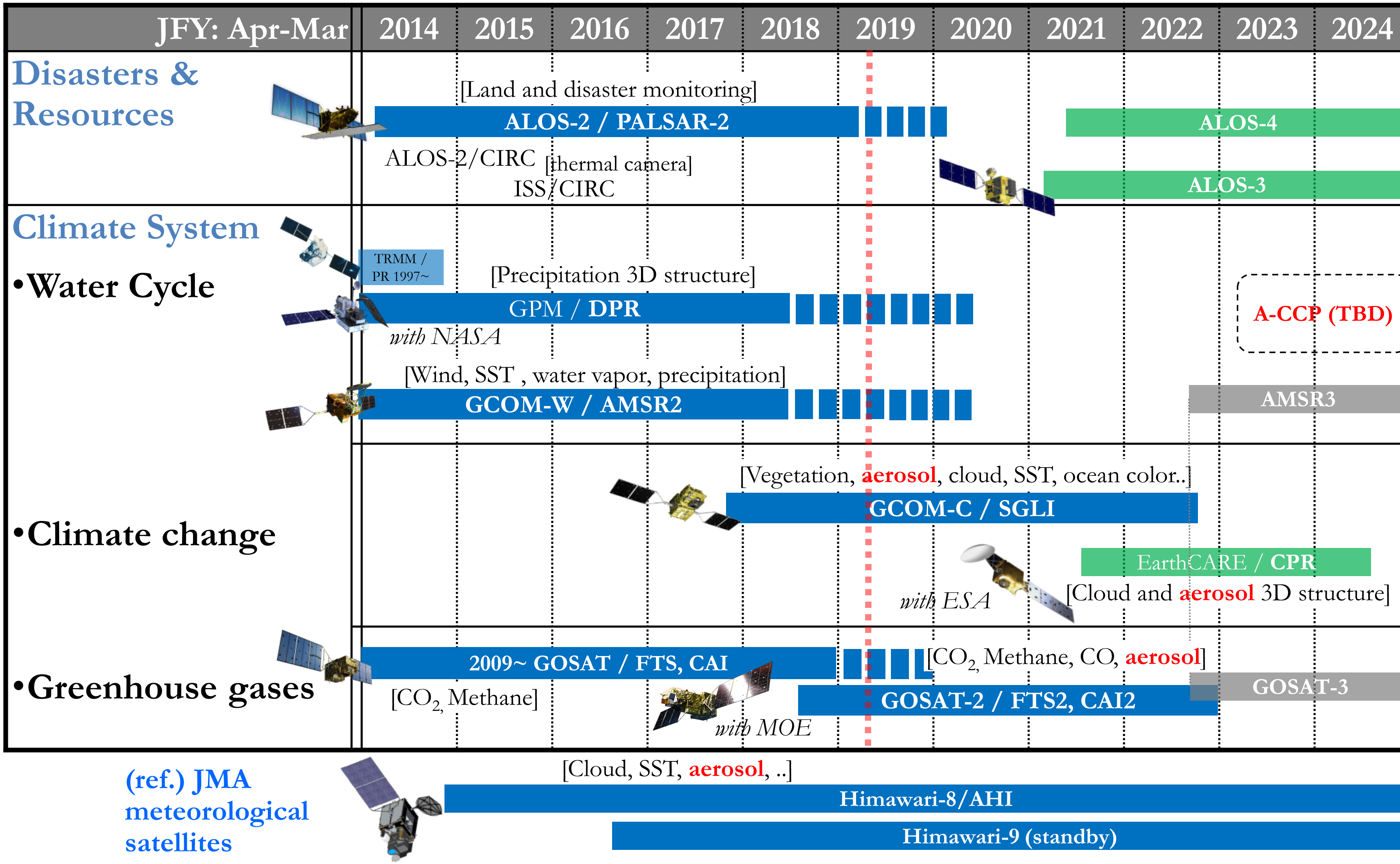
Hiroshi Murakami

JAXA/EORC

ICAP 2019 Tsukuba, Japan

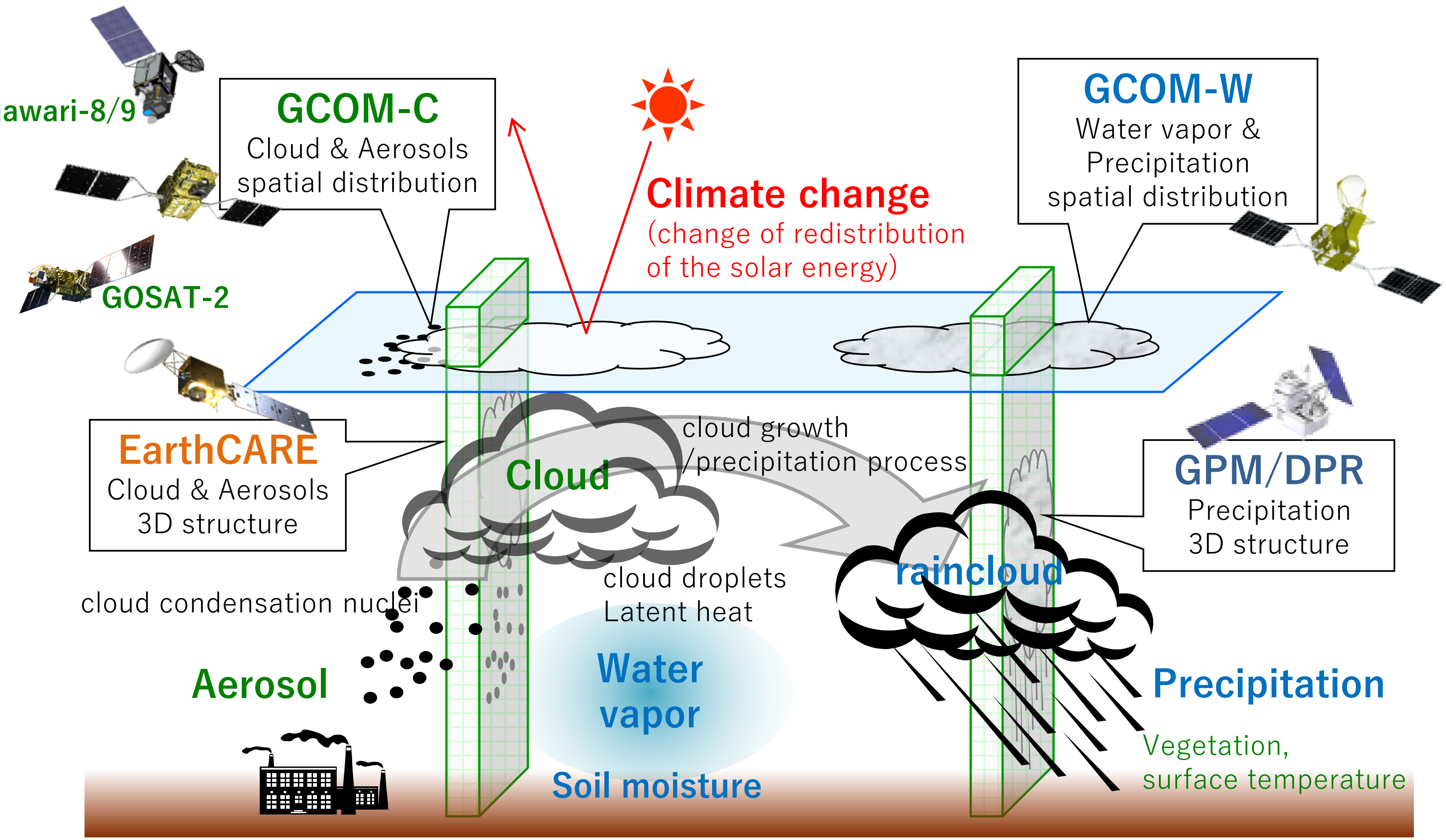
23 Jul. 2019

1.1 JAXA Earth observation satellite missions



Mission status: On orbit | Development | Study | Pre-phase-A

1.2 JAXA science targets relating with aerosols: "aerosol-cloud-precipitation system"



For the Earth system prediction and supporting the policy making through

- ✓ **Precise diagnosis of the current state** which is changing with the global warming
- ✓ **Understanding of the aerosol-cloud-precipitation system** → A-CCP

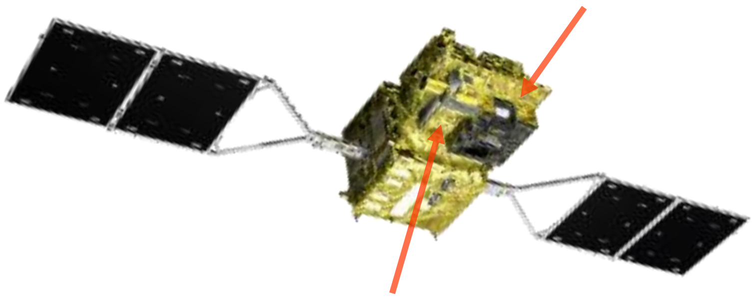
1.2 JAXA science targets: A-CCP Collaboration

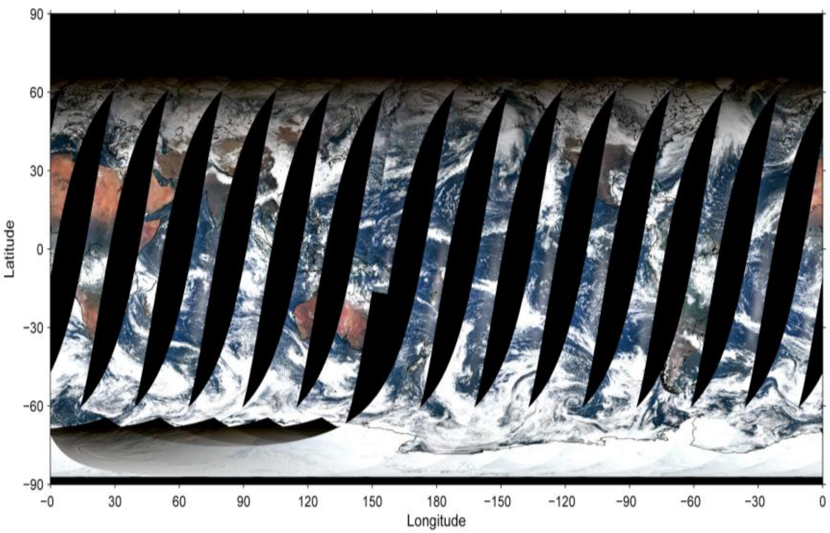
- ✓ **"Aerosol" and "Clouds, Convection and Precipitation" (A-CCP)** were selected as the Designated Observables by the US Decadal Survey issued last year
- ✓ NASA established international study team to formulate integrated observation scheme for A-CCP
  - satellites, airborne, ground-based observations, data buys, … etc.
- ✓ JAXA GPM + EarthCARE community has agreed to join the study team, and proposed to provide **next generation precipitation radar (DPR-2)** with following new/advanced functions improved from GPM/DPR

DPR-2 targets	DPR-2 function (requirement)
• To detect shallow & light rain/drizzle, snow • For more accurate global precipitation map	Higher Sensitivity than DPR
• To improve the model representation • World first observation of vertical motion of the precipitation	Doppler Velocity Observation
• To capture the whole structure of hurricane-scale phenomena • To improve the latency of global coverage • Direct use of radar for global precipitation map	Wider Swath than DPR 245km
• To get precise particle information	[optional] Polarimetric Observation

1.3 JAXA aerosol missions: GCOM-C/SGLI

Global Change Observation Mission – Climate (GCOM-C), Second-generation Global Imager (SGLI)



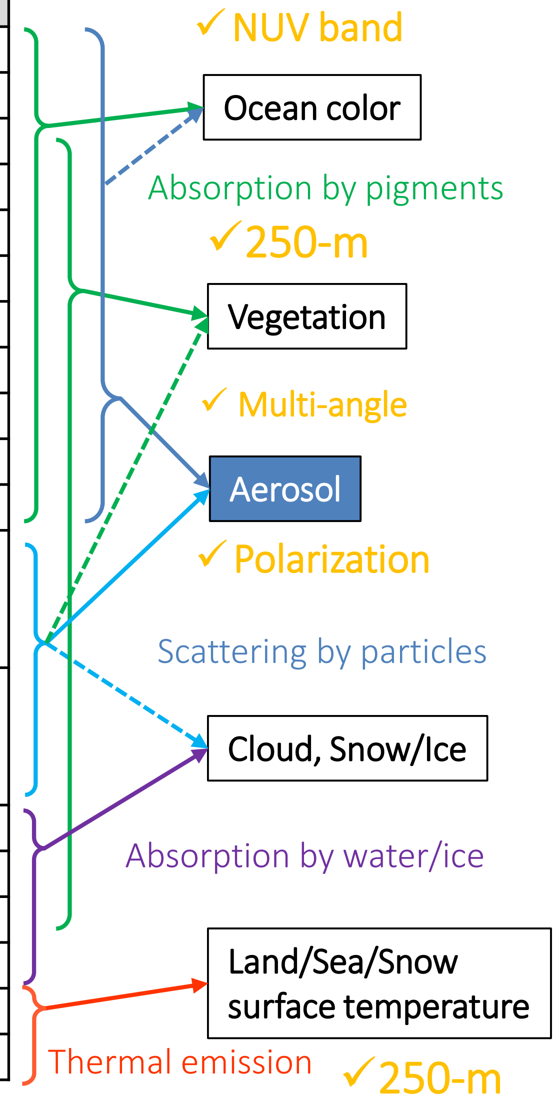


An example of SGLI/VNR daily coverage (5 Jan2018)

GCOM-C SGLI characteristics	
Launch Date	23 Dec. 2017
Weight	2,000kg
Orbit	Sun-synchronous (descending local time: 10:30), Altitude: 798km, Inclination: 98.6deg
Mission Life	5 years (3 satellites; total 13 years)
Scan	Push-broom electric scan (VNR) Wisk-broom mechanical scan (IRS)
Scan width	1150km cross track (VNR: NP & POL) 1400km cross track (IRS: SWIR & TIR)
Spatial resolution	250m (land and coast), 500m (TIR), 1km
Polarization	3 polarization angles for POL
Along track tilt	Nadir for VN, SW and TIR, & +/-45 deg for POL

1.3 JAXA aerosol missions: SGLI observation channels

Sub-system	channel	Center wavelength	width	Standard radiance	Saturation radiance	SNR	Pixel size
		nm		W/m^2/sr/μm or Kelvin		TI: NEΔT	m
Visible and Near Infrared Radiometer (VNR)	VN01	379.9	10.6	60	240-241	624-675	**250**/1000
	VN02	412.3	10.3	75	305-318	786-826	**250**/1000
	VN03	443.3	10.1	64	457-467	487-531	**250**/1000
	VN04	490.0	10.3	53	147-150	858-870	**250**/1000
	VN05	529.7	19.1	41	361-364	457-522	**250**/1000
	VN06	566.1	19.8	33	95-96	1027-1064	**250**/1000
	VN07	672.3	22.0	23	69-70	988-1088	**250**/1000
	VN08	672.4	21.9	25	213-217	537-564	**250**/1000
	VN09	763.1	11.4	40	351-359	1592-1746	250/**1000**
	VN10	867.1	20.9	8	37-38	470-510	**250**/1000
	VN11	867.4	20.8	30	305-306	471-511	**250**/1000
	PL01 +60	672 .2	20.6	25	295	609	**1000**
	PL01 +0				315	707	
	PL01 –60				293	614	
	PL02 +60	866.3	20.3	30	396	646	**1000**
	PL02 +0				424	763	
	PL02 –60				400	752	
Infrared Scanner (IRS)	SW01	1050	21.1	57	289.2	951.8	**1000**
	SW02	1390	20.1	8	118.9	347.3	**1000**
	SW03	1630	195.0	3	50.6	100.5	**250**/1000
	SW04	2210	50.4	1.9	21.7	378.7	**1000**
	TI01	10785	756	300K	340K	0.08K	**250**/500/1000
	TI02	11975	759	300K	340K	0.13K	**250**/500/1000



Cited from Okamura et al., 2018. SNR is defined at the standard radiance and IFOV shown by bold characters

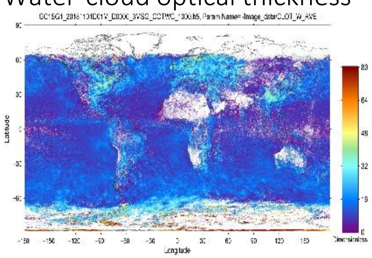
1.3 JAXA aerosol missions: GCOM-C products

✓ GCOM-C products have evaluated by using in-situ observations and other satellite data

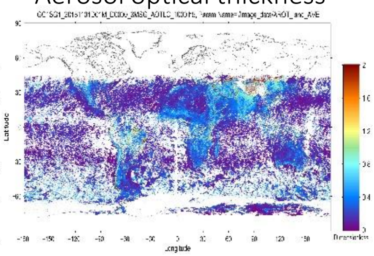
(https://suzaku.eorc.jaxa.jp/GCOM_C/data/validation.html)

✓ All standard products (Level-1, 2, and 3) have been open to the public via JAXA data portal, "G-Portal" (GUI data search and direct FTP are available; https://gportal.jaxa.jp/gpr/)

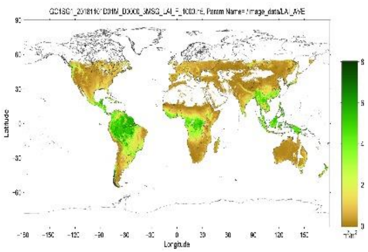
Water-cloud optical thickness



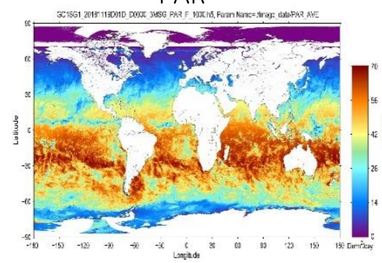
Aerosol optical thickness



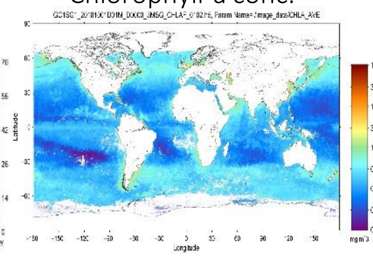
Leaf area index



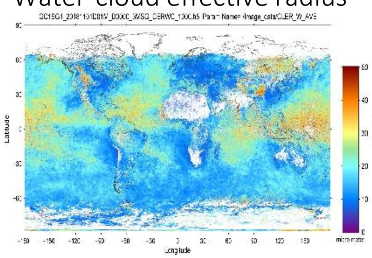
PAR



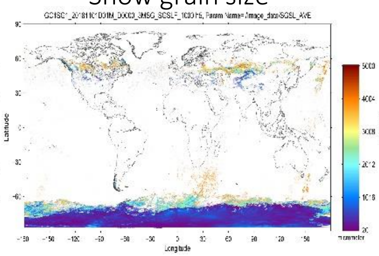
Chlorophyll-a conc.



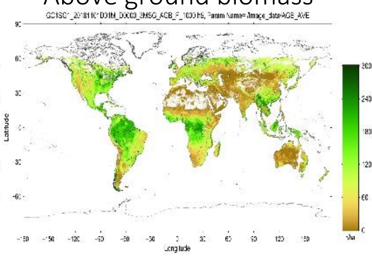
Water-cloud effective radius



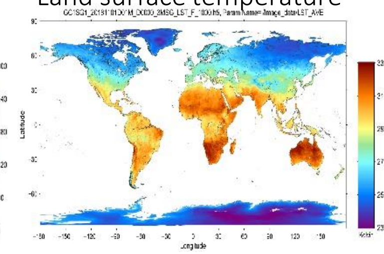
Snow grain size



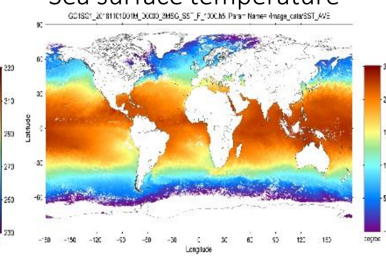
Above ground biomass



Land surface temperature



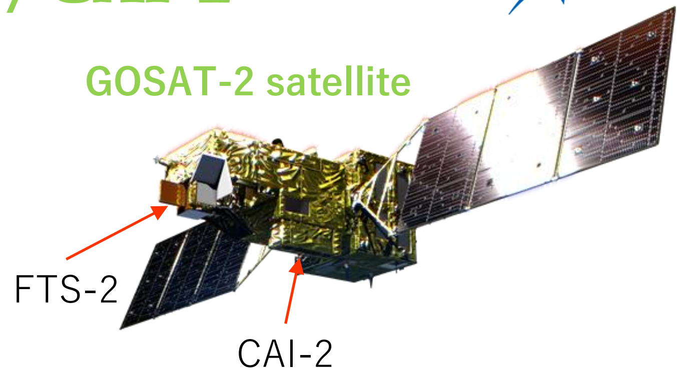
Sea surface temperature



1.3 JAXA aerosol missions: GOSAT-2/CAI-2

- Greenhouse gases Observing SATellite-2 (GOSAT-2) Thermal And Near Infrared Sensor for carbon Observation - Cloud and Aerosol Imager-2 (TANSO-CAI-2)

- The CAI-2 standard aerosol product will be produced by "**the multiwavelength and multipixel method**" (Hashimoto and Nakajima JGR 2017) which uses general characteristics of heterogeneous land surface reflectance and smoothly distributed aerosol over the surfaces.



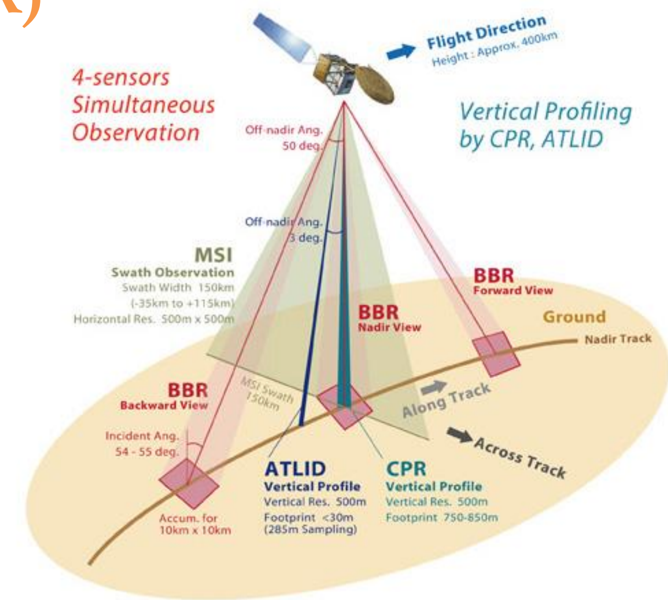
GOSAT-2	
Launch	Oct. 29 2018
Orbit type	Sun synchronous (dec 13:00 ± 0:15)
Altitude	613 km
Repeat cycle	6 days
Mass	< 2,000 kg
Power	5.0 KW

First image of CAI-2

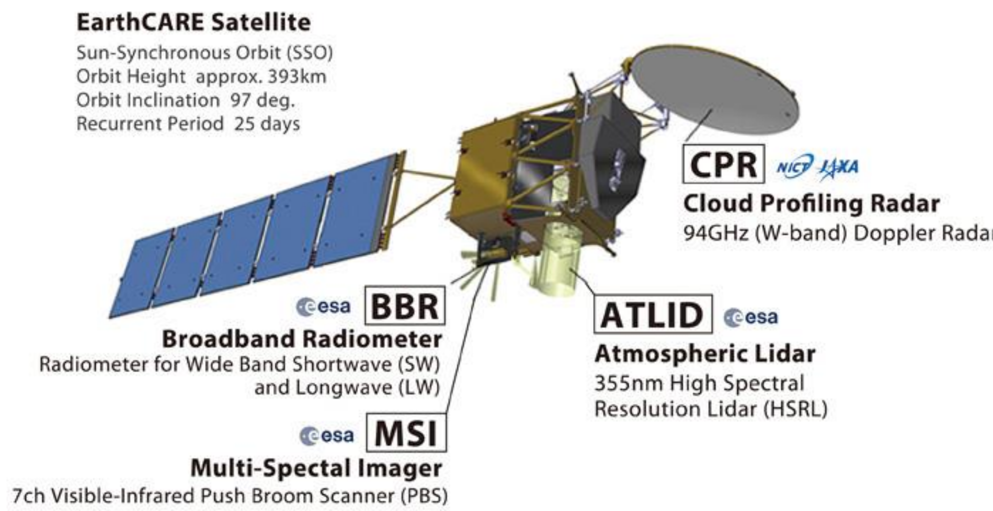
CAI-2 bands	nm	Tilt	Spatial resolution	Swath
B1	333 - 353	+20 deg. (Forward viewing)	460 m	920 km
B2	433 - 453			
B3	664 - 684			
B4	859 - 879			
B5	1585 - 1675		920m	
B6	370 - 390	-20 deg. (Backward viewing)	460 m	
B7	540 - 560			
B8	664 - 684			
B9	859 - 879			
B10	1585 - 1675		920m	

1.3 JAXA aerosol missions:
EarthCARE/Cloud Profiling Radar (CPR)

- EarthCARE will observe 3D structure of clouds and aerosols, and reduce errors in climate change and weather forecast, by Japan (JAXA/NICT)-Europe (ESA) cooperation.
- CPR is the world's first W-band Doppler radar (94GHz) aboard a satellite. We can understand the vertical structure of clouds, as well as the ascending and descending movement of clouds.

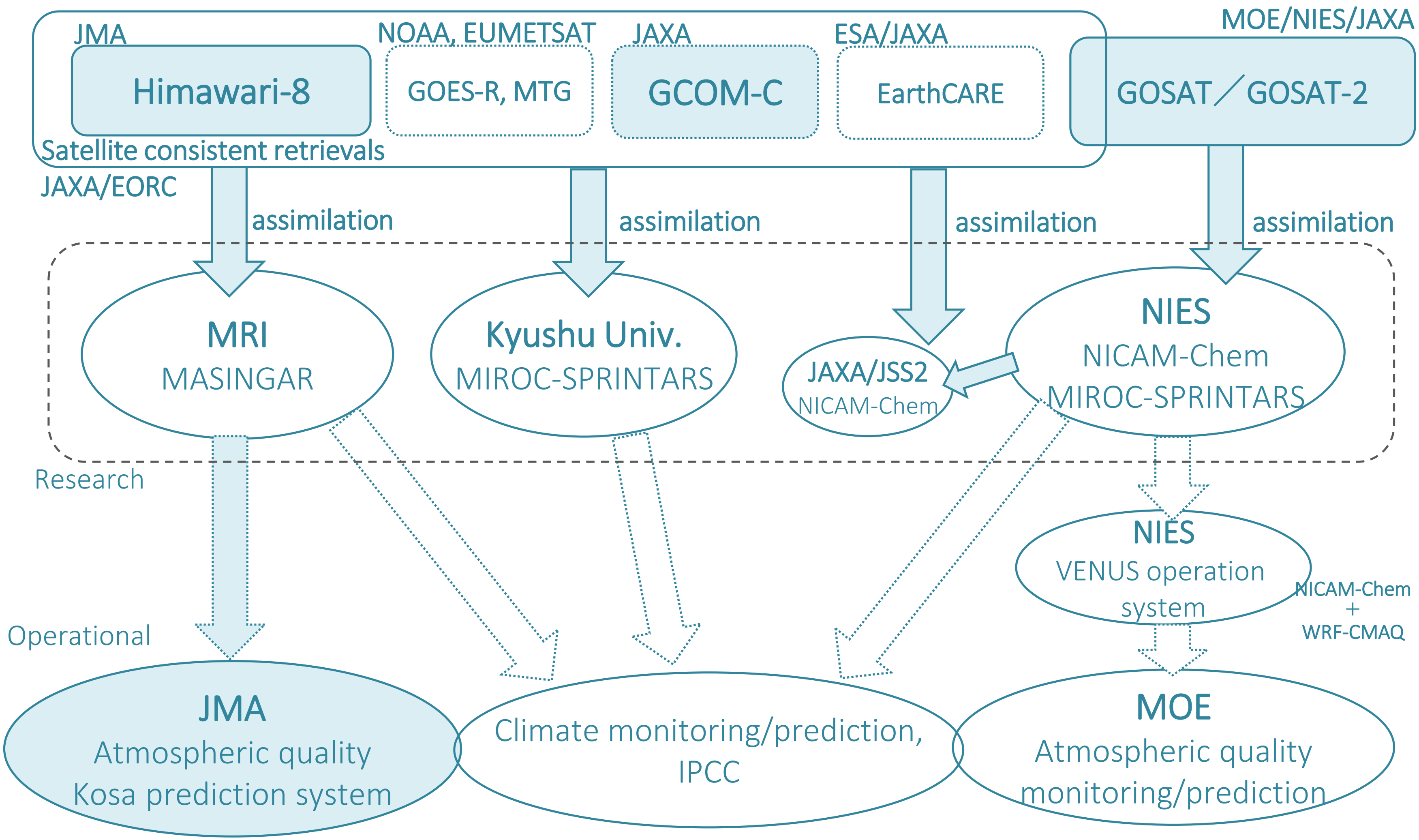


- **Mission**
  - Vertical profile of clouds, aerosol
  - Interaction between clouds and aerosol
  - Cloud stability and precipitation
- **Orbit**
  - Sun synchronous (13:45)
  - Altitude 400km
- **Task sharing**
  - JAXA/NICT (CPR)
  - ESA (LIDAR, MSI, BBR, Spacecraft)
- **Launch target**
  - JFY2021



1.3 JAXA aerosol missions:

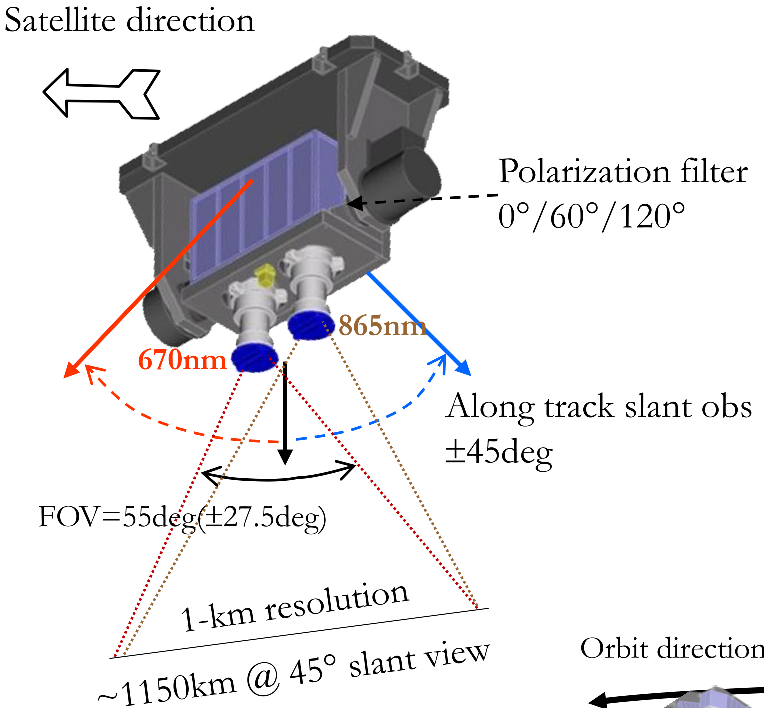
Integration of multiple satellite data through model assimilations



2. Aerosol observation by SGLI polarimetry

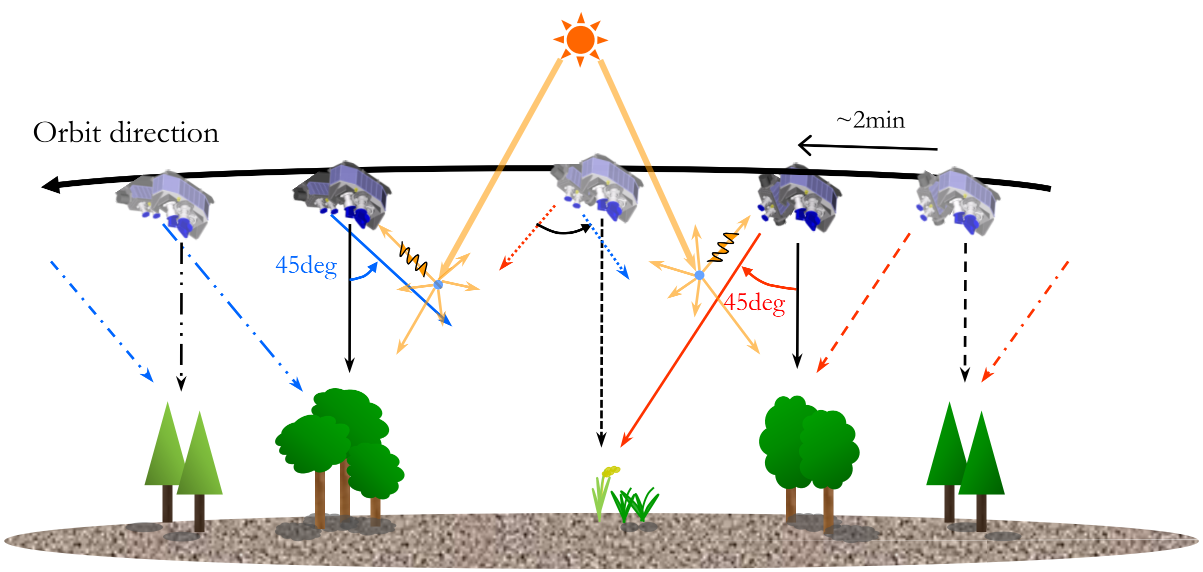
2.1 SGLI polarimetry

SGLI slant-view polarization observation



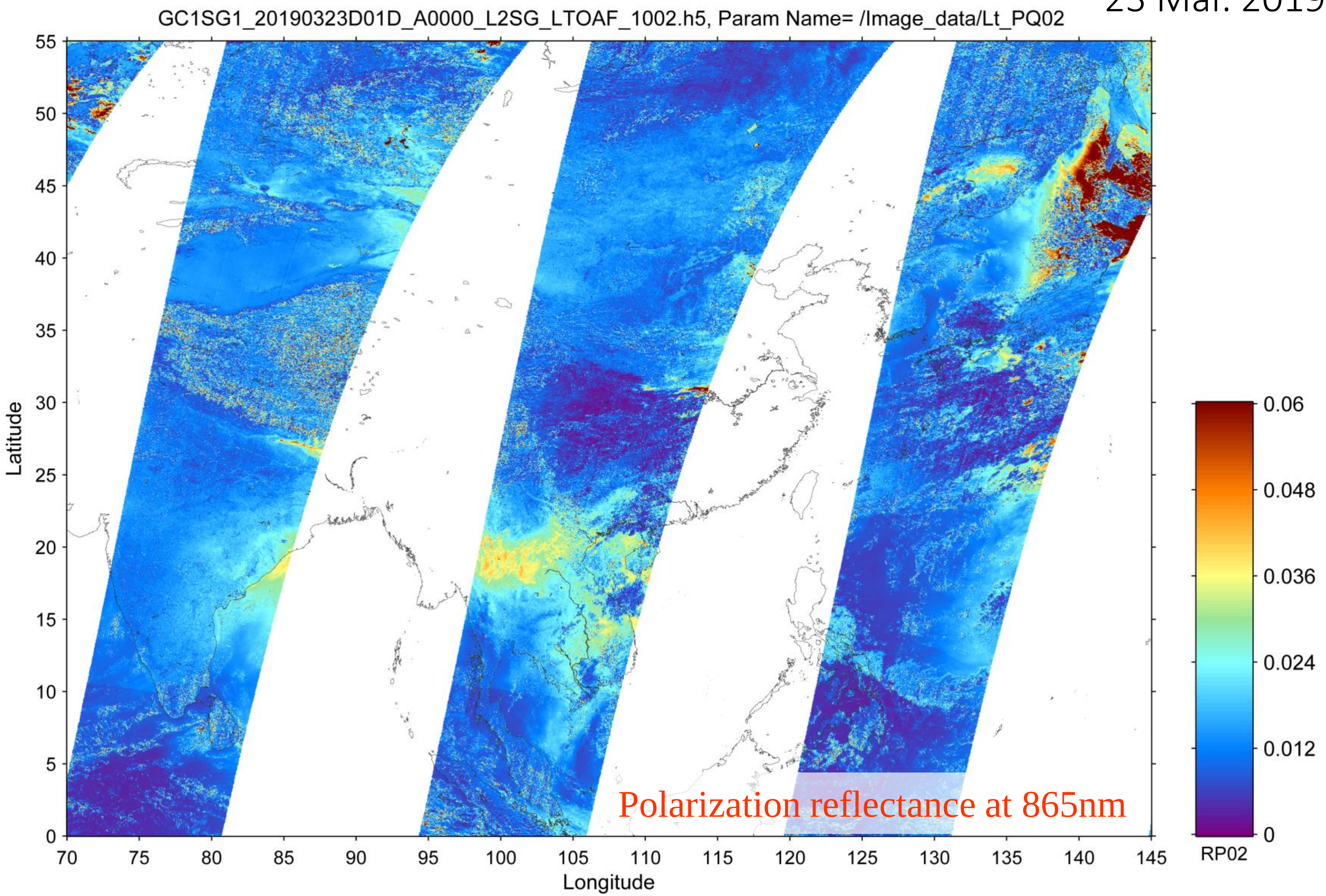
Along-track ±45deg tilt for polarization observation (I, Q, U @ 670nm and 865nm) of the atmospheric scattering

- "I component" can be used with nadir telescopes as multiangle observation of the land surface

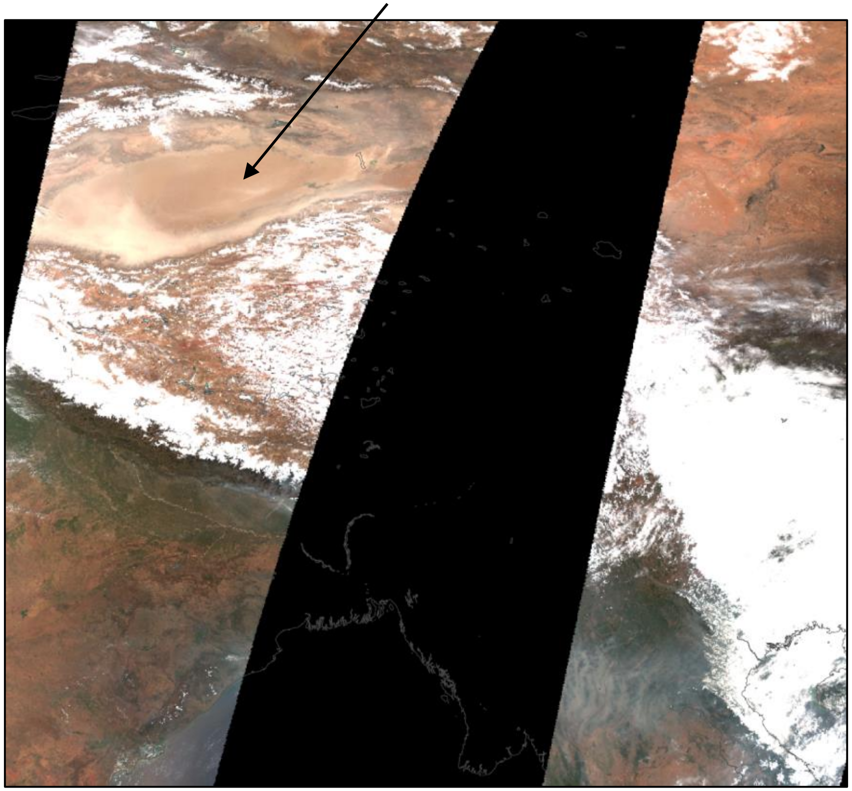


2.2 Aerosol by SGLI polarimetry

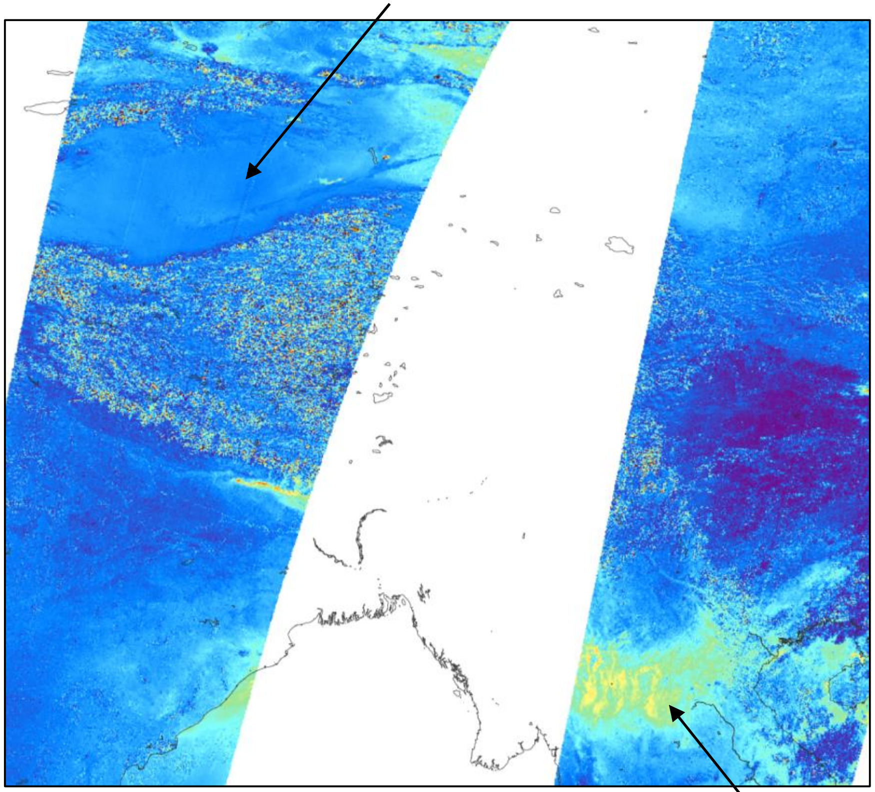
23 Mar. 2019



2.2 Aerosol by SGLI polarimetry



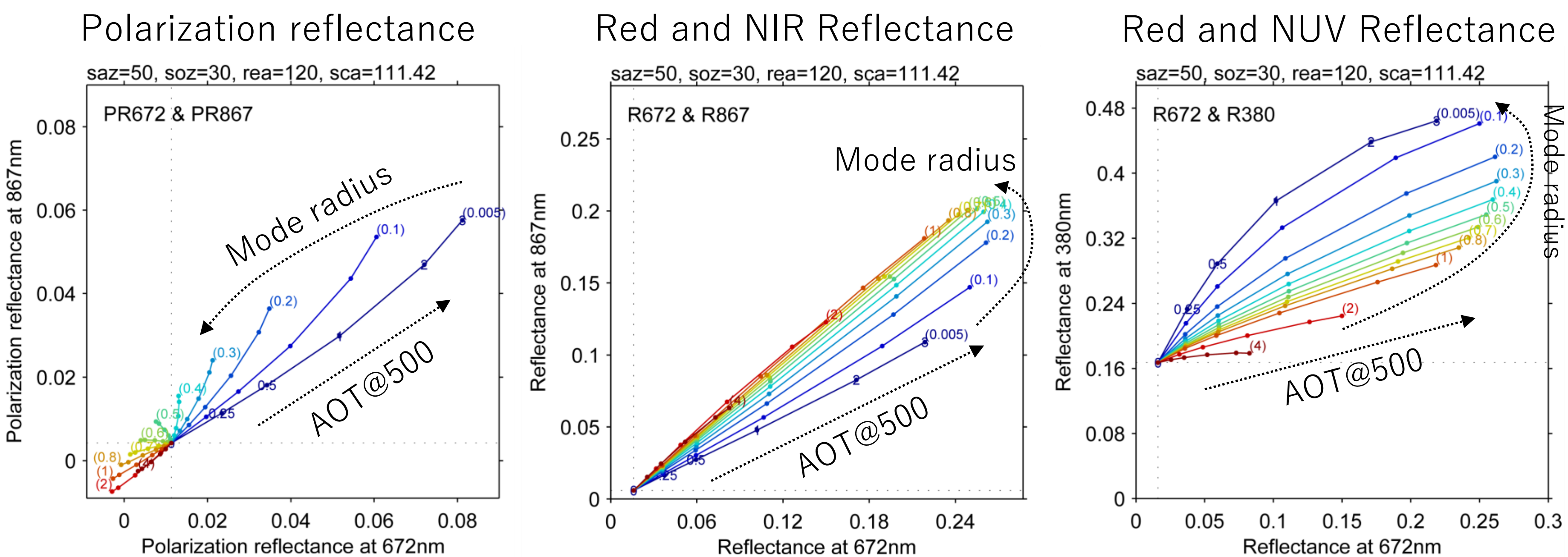
SGLI RGB image on 23 Mar. 2019



SGLI Polarization reflectance at 866nm on 23 Mar. 2019

- ✓ SGLI polarimetry captures fine mode aerosols (does not sensitive to the large dust (and cloud) particles

2.2 Aerosol by SGLI polarimetry: Sensitivity test by RTM



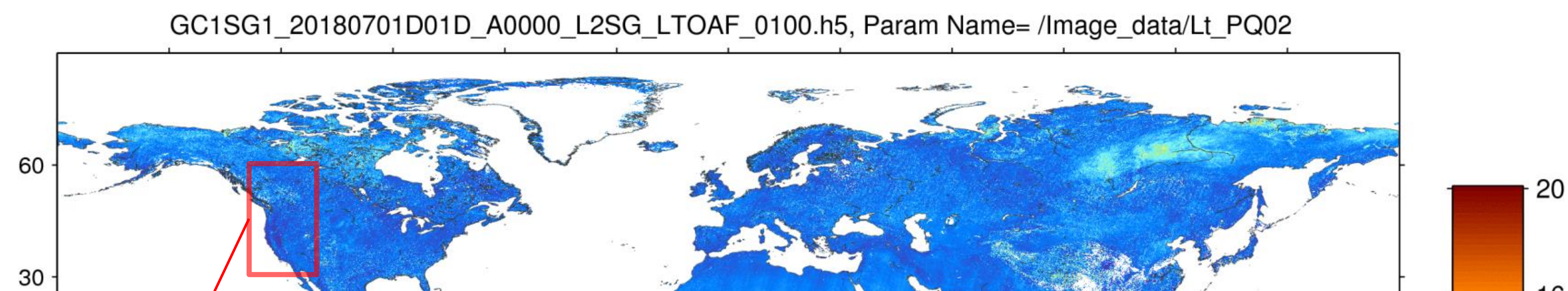
TOA reflectance calculated by Pstar4 (Ota et al., 2010)

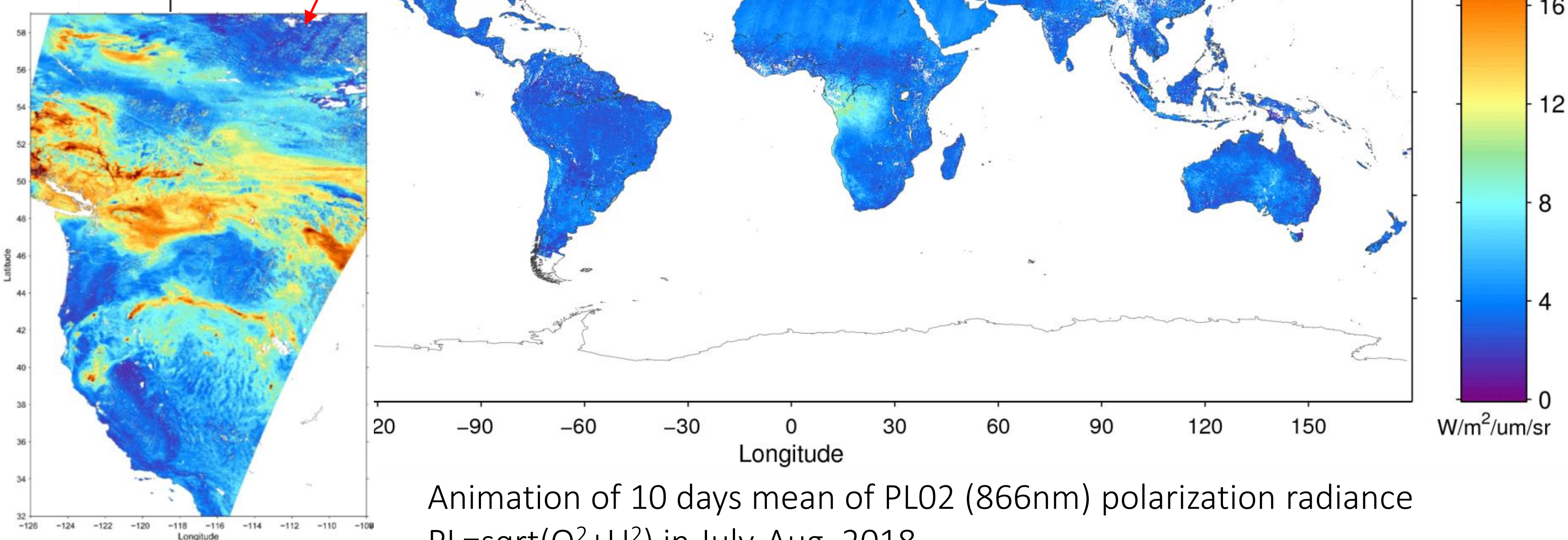
Merit of the polarimetry (compared with the reflectance method) in the aerosol estimation:

- ✓ Influence of land surface reflectance is relatively small
- ✓ Influence cloud contamination is relatively small
- ✓ Longer wavelengths (generally lower absorption) can be used for land areas

Demerit: strong sunglint contamination over water areas

2.2 Aerosol by SGLI polarimetry: examples (1)

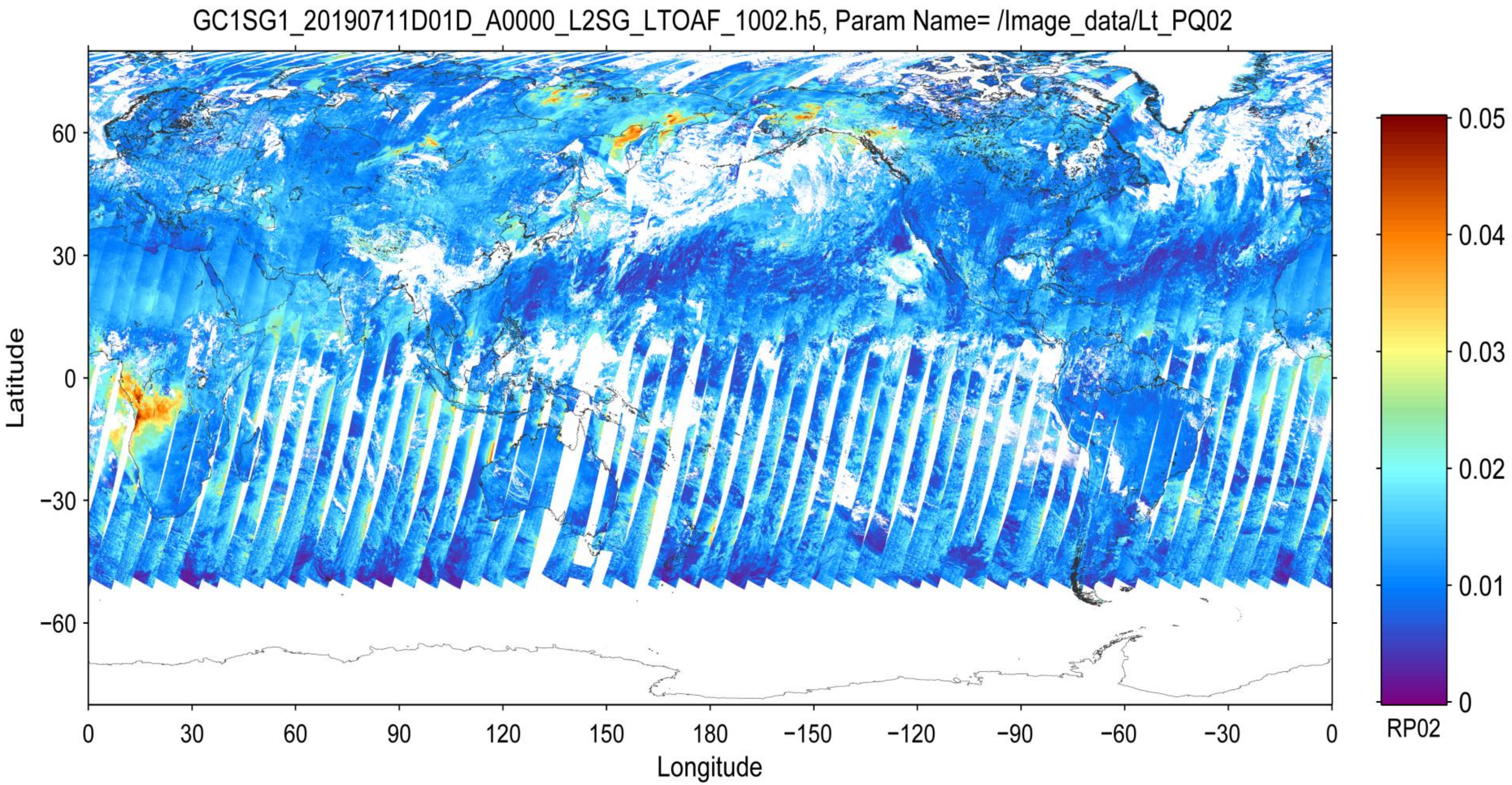




Animation of 10 days mean of PL02 (866nm) polarization radiance
PL=sqrt(Q^2+U^2) in July-Aug. 2018

✓ SGLI polarization radiance clearly shows the fine-mode aerosol distribution

2.2 Aerosol by SGLI polarimetry: examples (2)



✓ Fire smokes are observed in Alaska, Siberia-NE Asia, and Africa in Jun-Jul 2019

2.3 Aerosol by SGLI polarimetry:

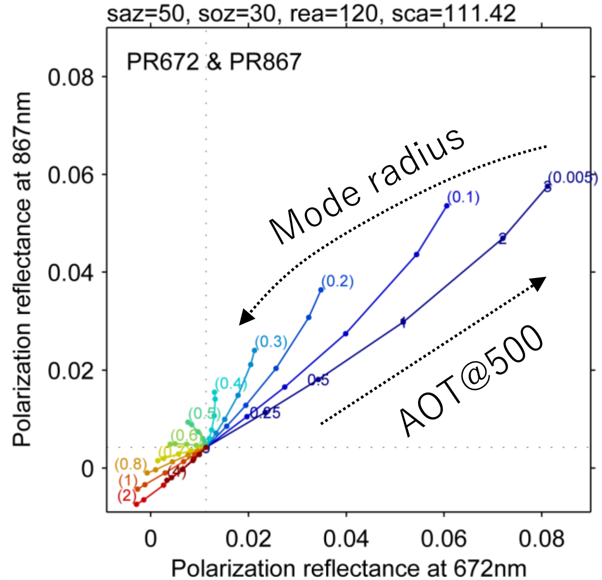
AOT estimation by SGLI polarimetry

(1) Surface polarization is estimated by clearest day data in the past 60-days

(2) Cloud and sunglint are masked by I component and geometry

(3) AOT is searched by polarization reflectance, R_p at 865nm and 670nm in the spider map

Polarization reflectance



TOA polarization reflectance calculated by Pstar4 (Ota et al., 2010)

$$R_p(\lambda) = \mathrm{sqrt}\,(\,Q(\lambda)^2 + U(\lambda)^2\,)\,\pi\,/\,F_0(\lambda)\,/\cos(\theta_0)$$

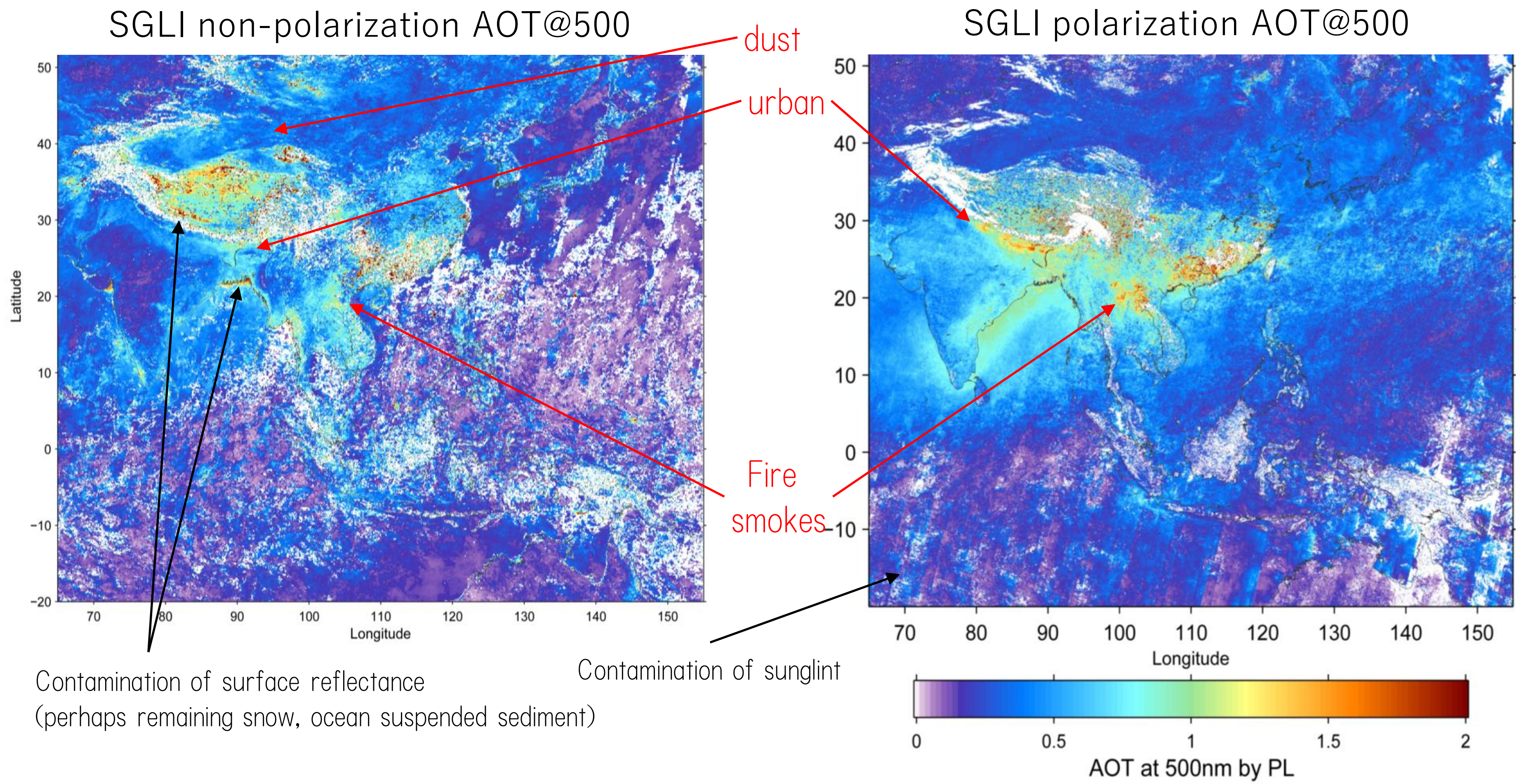
λ = 865nm, 670nm

Q, U: Q and U component of the stokes vector (I, Q, U, V); V component is ignored

2.3 Aerosol by SGLI polarimetry:

Comparison of AOT estimates between non-polarization and polarization methods

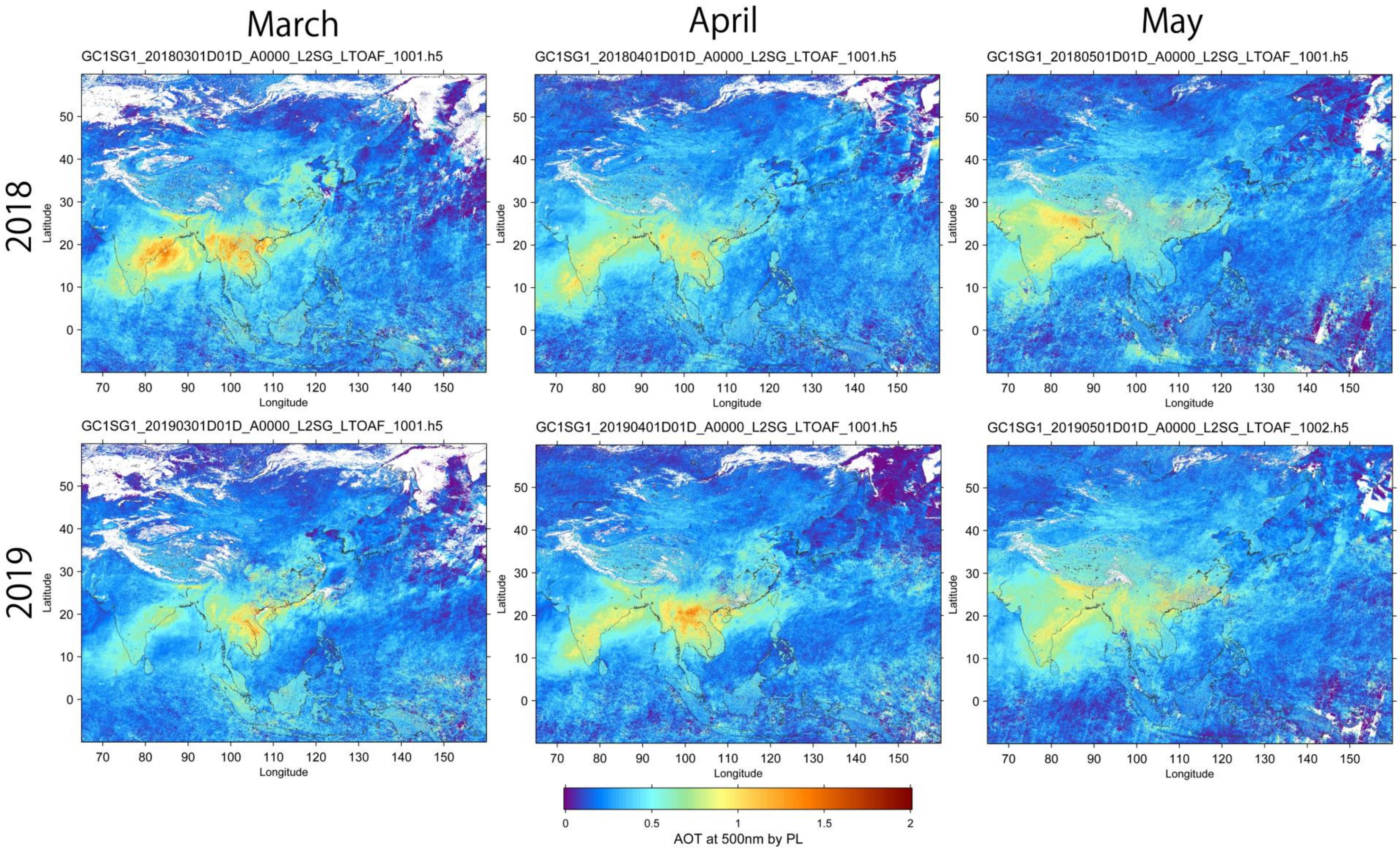
(Monthly average in May 2019)



- ✓ Overall distribution is similar between the non-POL and POL methods
- ✓ Cloud contamination on POL AOT is smaller due to the low polarization of cloud particles

2.3 Aerosol by SGLI polarimetry:

Monthly AOT500 by polarization in Spring 2018/2019



✓ Heavy aerosols were captured in Thailand in April 2019

3. Summary

- JAXA is operating polar orbit satellite missions, GCOM-C and GOSAT2, and will have EarthCARE for the aerosol observation
- A sensor common algorithm is developed in JAXA/EORC (will be presented by Dr. Yoshida tomorrow)
- Satellite AOT assimilation is investigated with JMA/MRI, Kyusyu Univ., AORI, and NIES
- The aerosol-cloud-precipitation system is the next key science target with A-CCP
- GCOM-C/SGLI polarimetry shows good possibilities to improve estimation of the fine mode aerosols