JAXA EO Program and Opportunities for GEWEX

Misako KACHI*, Riko OKI
and Teruyuki NAKAJIMA
Japan Aerospace Exploration Agency
(JAXA)

GEWEX SSG-32, 27-30 Jan. 2020, Pasadena, US

Japanese Earth Observation Satellites

Targets (JFY: Apr-Mar)	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Disasters & Resources JERS1/OPS, SAR (1992-1998) ADEOS-I/AVNIR ALOS/AVNIR2, PALSAR (2006-2011)	[Land and disaster monitoring] ALOS-2 / PALSAR-2							[Land and disaster monitoring] ALOS-4/Advanced SAR				
							[Land and disaster monitoring] ALOS-3/Advanced Optical					
Climate System **•Water Cycle** *with NASA* ADEOS-II/AMSR (2003) Aqua/AMSR-E (2002-2011)	TRMM / PR	[Precipitation 3D structure]					Feasibility study					
	GPM / DPR *with NASA*											
	[Wind, SST , water vapor, rainfall] GCOM-W / AMSR2								[Wind, SST , water vapor, precipitation]	GOSAT-GW/AMSR3		
•Climate change ADEOS-I/OCTS (1996-1997) ADEOS-II/GLI (2003)	[Vegetation, aerosol, cloud, SST, ocean color] GCOM-C / SGLI											
									[Cloud and aerosol 3D structure] EarthCARE / CPR *with ESA*			
•Greenhouse gases	[CO_2, CH_4] GOSAT / FTS, CAI *with MOE*									[CO_2, CH_4, CO] GOAT-GW/TANSO-3 *with MOE*		
					[CO_2, CH_4, CO] *with MOE*		GOSAT-2					
JMA geostationary meteorological satellites	MTSAT-1R (Himawari-6)						Himawari-10/11 planning					
	MTSAT-2 (Himawari-7)					[Cloud, aerosol, SST]						
	Himawari-8									Himawari-8 (standby)		
	Himawari-9 (standby)									Himawari-9		

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

Satellites' Contributions to ECVs

Total Essential Climate Variables (ECVs)	54

ECVs measured by GCOM-C&W, GPM/DPR and GOSAT	24

GCOM-C | GCOM-W | GPM/DPR | GOSAT, GOSAT-2 | ALOS-2

Atmosphere

Surface	Upper-air	Atmospheric Composition
Precipitation	Earth radiation budget	Aerosol and ozone precursors
Pressure	Lightning	Aerosols properties
Radiation budget	Temperature	Carbon dioxide, methane & other greenhouse gases
Temperature	Water vapour	Cloud properties
Water vapour	Wind speed & direction	Ozone
Wind speed and direction		

Land

Biosphere	Hydrosphere
Above-ground biomass	Groundwater
Albedo	Lakes
Evaporation from land	River discharge
Fire	**Anthroposphere**
Fraction of absorbed photosynthetically active radiation (FAPAR)	Anthropogenic Greenhouse gas fluxes
Land cover	Anthropogenic water use
Land surface temperature	**Cryosphere**
Leaf area index	Glaciers / Snow
Soil carbon	Ice sheets and ice shelves
Soil moisture	Permafrost

Ocean

Physical

Ocean surface heat flux		
Sea ice	Sea level	Sea state
Sea surface currents		
Sea surface salinity		
Sea surface stress		
Subsurface salinity		
Sea surface temperature		
Subsurface currents		
Subsurface temperature		

Biogeochemical

Inorganic carbon	Transient tracers
Nitrous oxide	Nutrients
Ocean colour	Oxygen

Biological/ecosystems

Marine habitat properties
Plankton

Recent Highlights of JAXA Earth Observations

Mission/Planning

- Development of "Grand Plan for Water Cycle Observations by Satellites" (Apr. 2019)
- Approval of new mission: GOSAT-GW carrying AMSR3 and GOSAT-2 f/o (Dec. 2019)
- Feasibility study on Next Generation Precipitation Radar (ongoing)

Data/Web site

- Data Release of GCOM-C/SGLI (Dec. 2018)
- Reprocessing of Aqua/AMSR-E geophysical parameter Ver.8 (Apr. 2019)
- Data release of GOSAT-2 Level 1 (Aug. 2019)
- Extension of "Global Rainfall Realtime (GSMaP_NOW)" to global coverage (Jun. 2019)
- Open of "JAXA 3D Rainfall Watch" web site (Jul. 2019)
- Capturing large melting of Greenland ice sheet (Jun. & Aug. 2019)
- Capturing second minimum Arctic sea ice extent (Sep. 2019)

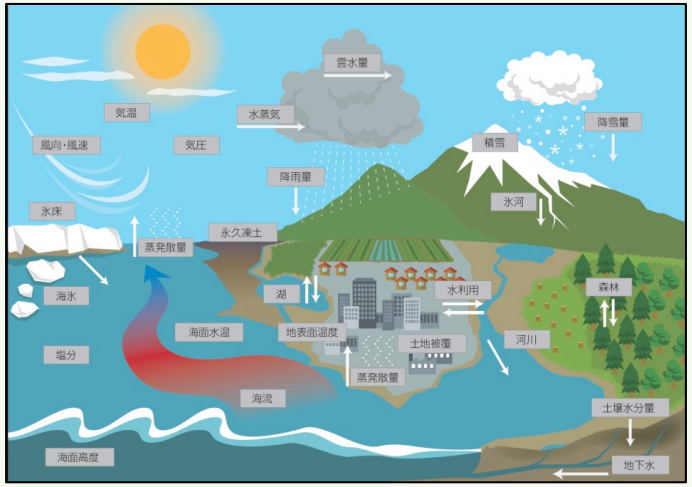
Researches/Collaborations

- Contributions to WMO SEMDP initiative with GSMaP
- Start collaboration with JMA for the GSMaP for developing regional integrated precipitation product by using ground/space observation in RSMC Tokyo for Nowcasting (Mar. 2019)
- Operational 3-hr nowcasting of GSMaP_NOW with Japan Weather Association (Apr. 2019)
- Release of 1-km resolution land/river simulation in Japan "Today's Earth – Japan" with the Univ. Tokyo (Nov. 2019)
- Operational aerosol forecast assimilating Himawari-8 aerosol data with JMA (Jan. 2020)

The Grand Plan for Water Cycle Observation by Satellites

Target: Utilize Japanese satellite observation to contribute policy making of adaptation/action for impact of climate change and operational application to provide information of water disaster & NWP through solution of scientific challenges of future water distribution and prediction

Chap.2 Importance of water cycle studies and role of satellite observations



Scientific challenges to be addressed in Japan

1. **Quantification of water cycle parameters**
2. **Understanding of cloud-precipitation process**
3. **Monitoring of changes in Cryosphere**

Climate change monitoring & improvement of prediction accuracy

Chap.3 Current status of satellite water cycle observations in the world/ achievements in Japan

Chap.4 Identification of challenges to be solved by satellite and model

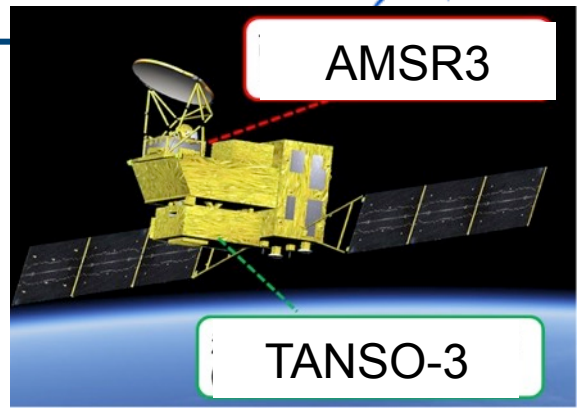
- Improvement of monitoring of current status of cloud-precipitation process
- Improvement of weather forecast by data assimilation
- Upgrading integrated use with hydrological models
- Clarification of impacts of climate change to cloud-precipitation system
- Monitoring of water-energy flux variation between atmosphere-ocean and clarification of impacts by climate change
- Clarification and modeling of water cycle variation over land by climate change
- Clarification of cloud-precipitation process and improvement of prediction accuracy by model upgrades
- Monitoring of ice/snow distribution and improvement of short-term prediction
- Monitoring of environmental change in polar ice/snow and clarification of water budget process
- Prediction of polar and sea ice variation including impacts of global warming

Chap.4 Organizing future mission requirements to solve scientific challenges

- Organize requirements to satellite observation to solve above challenges (continuity, new geophysical parameters, improvement of sensor function/performance)
- **High priority: microwave imager, precipitation radar**
- Others: global optical imager, hyper-spectrum infrared/microwave sounder, wind lidar, large antenna microwave imager on geostationary, geostationary sounder, small satellite constellations

Identified three scientific challenges, where satellite is useful and to be addressed in Japan by both satellite observations and model studies, among various issues in water cycle studies, and clarified requirements for future satellite missions.

GOSAT-GW: Global Observation SATellite for Greenhouse gases and Water cycle



- GOSAT-GW will carry two instruments, AMSR3 and TANSO-3.
  - AMSR3, led by JAXA, will succeed AMSR series observations adding new high-frequency channels for solid precipitation retrievals and water vapor analysis in NWP.
  - TANSO-3, led by Japanese Ministry of Environment (MOE), will improve observation capability of greenhouse gases from GOSAT-2/ TANSO-2.
  - Target launch is JFY2023.
- Targets of AMSR3
  - To produce long-term continuous data record
  - To enhance operational utilization of near-real time data
    - weather forecast including hurricane analysis
    - fishery in coastal area
    - navigational assistance on arctic shipping route
    - New geophysical parameter products

Orbit	**Type**	Sun-synchronous, Sub-recurrent orbit
	Altitude	666km, recurrent cycle 3days (same as GOSAT)
	MLTAN	13:30±15min (same as GCOM-W)
Mass		2.6 ton (Including propellant)
Power		> 5.3 kW
Design life		> 7 years
Launch vehicle		H-IIA rocket
Mission data downlink rate		Direct transmission with X-band: 400 Mbps Direct transmission with S-band: 1 Mbps (Only for AMSR3)
Instrument		TANSO-3 (for GHG) AMSR3 (for Water Cycle)

Specification of AMSR3 Instrument

Sensor type	Conical scanning total power microwave radiometer
Antenna	Off-set parabolic antenna (φ2.0m aperture)
Swath width	> 1530m
Quantization	12 bit
Incidence angle	55 deg. except 89GB, 166G,183G
X-polarization	< -20dB
Beam efficiency	> 90%
Range	2.7-340K
Sampling interval	5-10km
Data rate	87.4 kbps (average)
Life time	7 years

* Red indicates differences from AMSR2

Center frequency [GHz]	Polarization	Band width [MHz]	NEDT (1σ)	Beam width (spatial resolution)
6.925 7.3	H/V	350	< 0.34 K	1.8° (34km x 58km)
10.25 (TBD)	H/V	500 (TBD)	< 0.34 K (TBD)	1.2° (22km x 39km)
10.65	H/V	100	< 0.70 K	1.2° (22km x 39km)
18.7	H/V	200	< 0.70 K	0.65° (12km x 21km)
23.8	H/V	400	< 0.60 K	0.75° (14km x 24km)
36.5	H/V	1000	< 0.70 K	0.35° (7km x 11km)
89.0 A/B	H/V	3000	< 1.20 K	0.15° (3km x 5km)
165.5	V	4000	< 1.50 K (TBD)	0.3°(TBD) (6km×10km)
183.31±7	V	2000×2	< 1.50 K (TBD)	0.28°(TBD) (5km×9km)
183.31±3	V	2000×2	< 1.50 K (TBD)	0.28°(TBD) (5km×9km)

List of AMSR3 Products

Standard Product
Brightness Temperature (6-183GHz) (L1B)
Resampled Brightness Temperature (L1R)
Total Precipitable Water (over ocean & land)
Integrated Cloud Liquid Water Content (over ocean)
Precipitation (liquid & solid)
Sea Surface Temperature (6GHz & 4-frequency)
Sea Surface Wind Speed
All Weather Sea Surface Wind Speed
Sea Ice Concentration
High-resolution Sea Ice Concentration
Soil Moisture Content
Snow Depth (snow depth & SWE)

Research Product
High-resolution Brightness Temperature (6-10GHz) (L1H)
High-resolution Sea Surface Temperature (20km res.)
Sea Ice Motion Vector
Land Surface Temperature
Vegetation Water Content
Thin Ice Detection
Soil Moisture Content & Vegetation Water Content by Land Data Assimilation (L4)
Climate Data Record (CDR) for each parameter

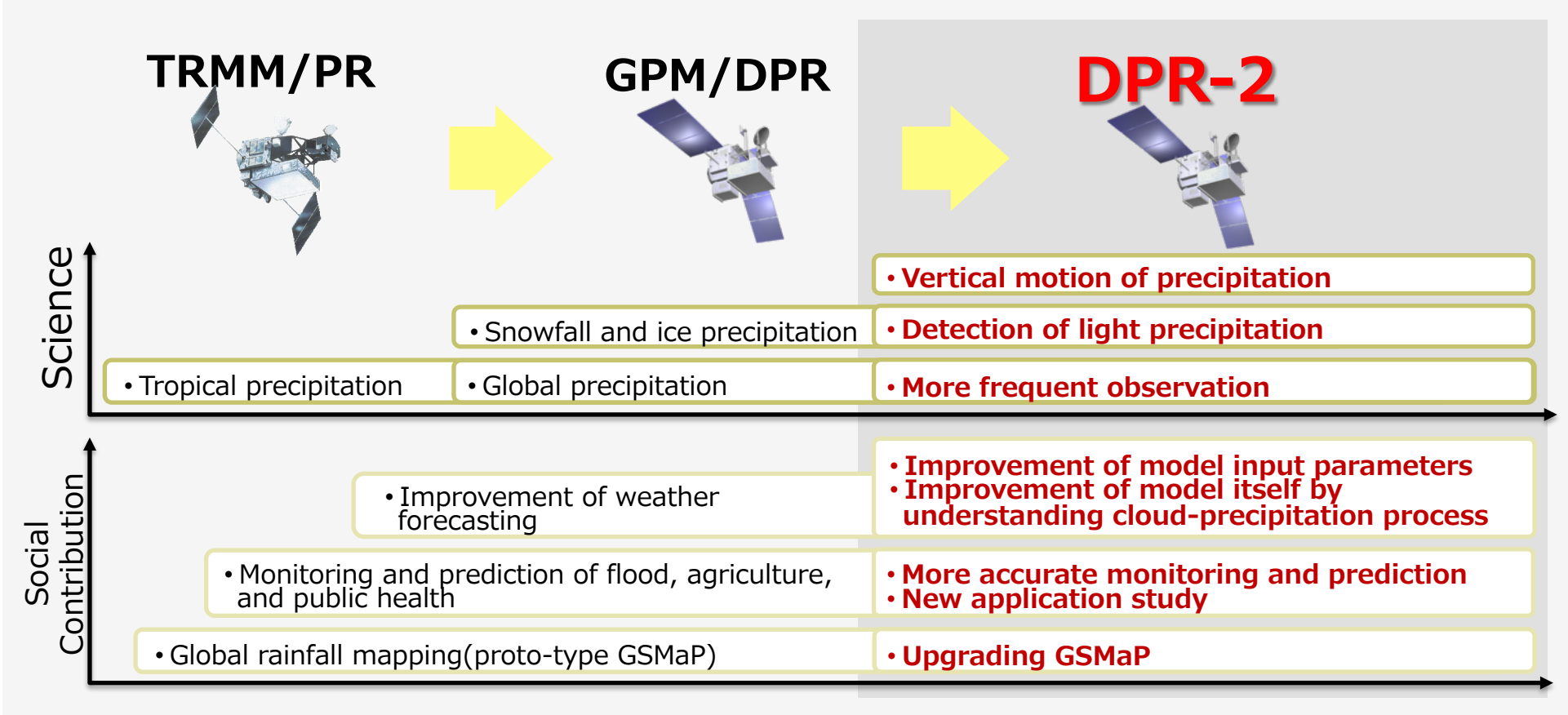
(as of Dec. 2019)

* Red indicates differences from AMSR2

8

Feasibility Studies for Next Generation Precipitation Radar

- PMM study subcommittee of future precipitation measurement mission in Japan summaries DPR follow-on sensor targets as follows;

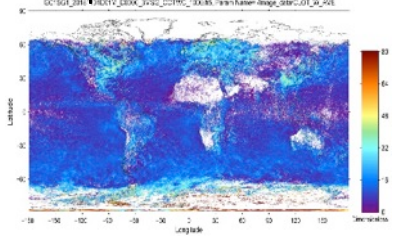


- To accomplish those targets, possible new specifications of DPR-2 will have; Doppler observation / Higher sensitivity / Wider swath
- Japan will contribute to NASA ACCP study with DPR-2.

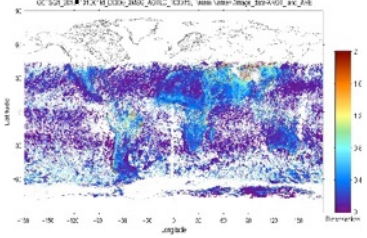
Data Release of GCOM-C/SGLI

https://gportal.jaxa.jp/gpr/

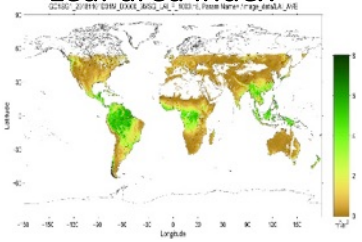
Water-cloud optical thickness



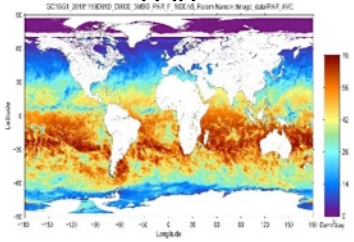
Aerosol optical thickness



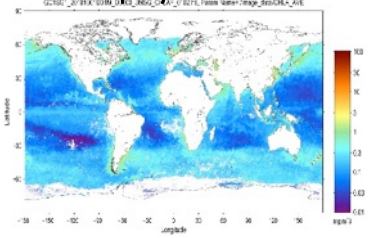
Leaf area index



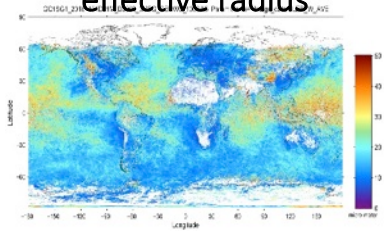
PAR



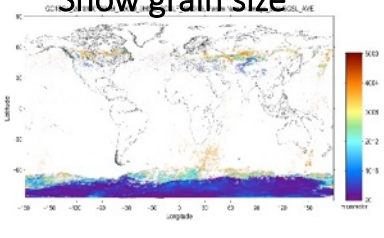
Chlorophyll-a conc.



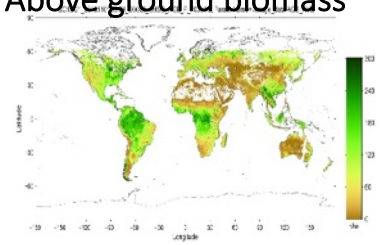
Water-cloud effective radius



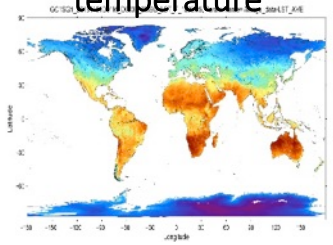
Snow grain size



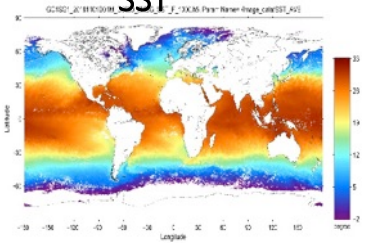
Above ground biomass



Land surface temperature



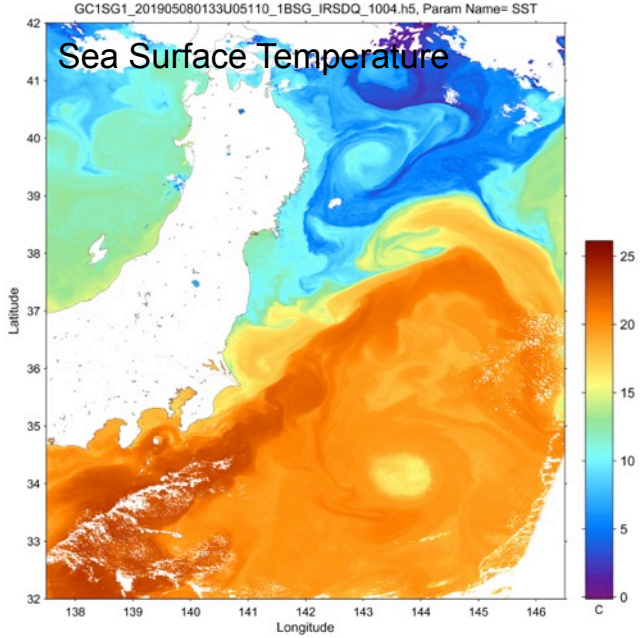
SST



◀ GCOM-C provides 29 data products from G-Portal

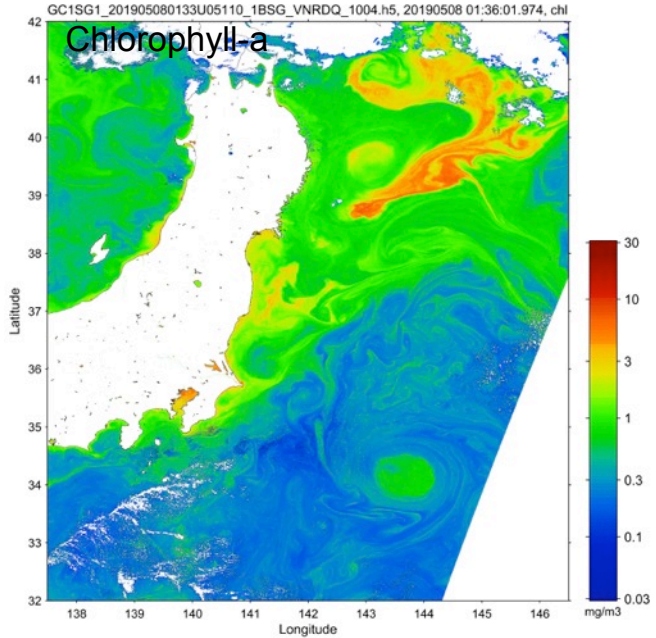
GC1SG1_201905080133U05110_1BSG_IRSDQ_1004.h5, Param Name= SST

Sea Surface Temperature



GC1SG1_201905080133U05110_1BSG_VNRDQ_1004.h5, 20190508 01:36:01.974, chl

Chlorophyll-a



◀ SGLI on GCOM-C has 250-m resolution and captured fine structures of ocean current and eddies.

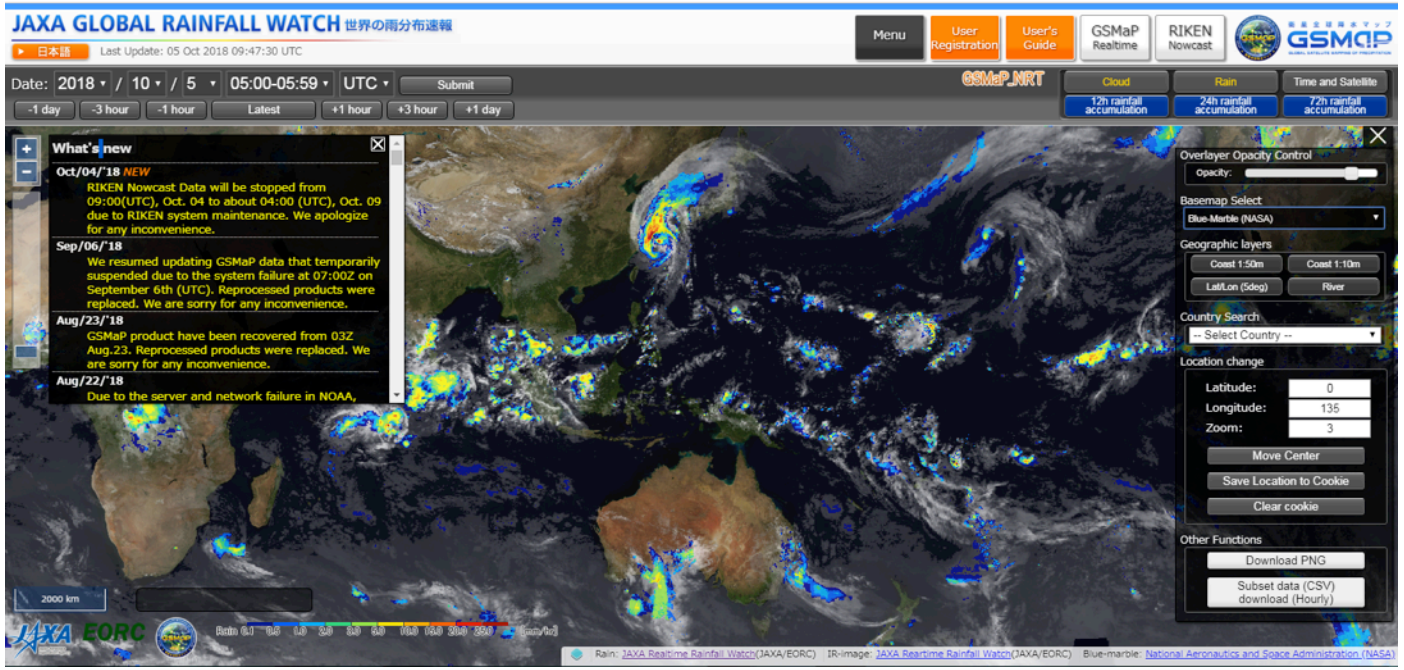
2019/05/08

AMSR-E Reprocessing toward Long-term Dataset

- AMSR-E L1 Ver.4 is available at the JAXA G-Portal (https://www.gportal.jaxa.jp/gp/)
- AMSR-E L2 Ver.8 has uploaded to the G-Portal since Apr. 2019 and completed uploading whole period in Jan. 2020.
- Comparison of accuracy is as follows;

Product (ID)	AMSR-E Ver. 7	AMSR-E Ver. 8	AMSR2 V2/3
Integrated water vapor (TPW)	1.89 kg/m^2	1.61 kg/m^2	1.5 kg/m^2
Integrated cloud liquid water (CLW)	0.0395 kg/m^2 (Jan./Jul. 2003)	0.0252 kg/m^2 (whole period)	0.04 kg/m^2
Precipitation (PRC)	Ocean 94.87 % Ocean 123.54 %	Ocean 65.92 % Land 91.13 %	Ocean 48% Land 86%
Sea surface temperature (SST)	0.62 deg.C	0.54 deg.C	0.5 deg.C
Sea surface wind speed (SSW)	1.164 m/s	0.979 m/s	1.0 m/s
Se ice concentration (SIC)	N.H. 6.66 % S.H. 8.10 %	N.H. 7.01 % S.H. 8.02 %	9 %
Snow depth (SND)	17.0 cm	17.7 cm	18 cm
Soil moisture content (SMC)	Mongolia 3.07 %vol U.S. LR 3.87 %vol	Mongolia 2.16%vol U.S. LR 4.88%vol	4 %vol

Global Satellite Mapping of Precipitation (GSMaP)



https://sharaku.eorc.jaxa.jp/GSMaP/

5491 registered users from 128 countries/ regions as of 31 Dec. 2019

- GSMaP is a blended Microwave-IR product and has been developed in Japan for the GPM mission.
  - A review paper of the GPM-era GSMaP products will appear in March 2020 (Kubota et al. 2020).
  - GPM-GSMaP V03 (algorithm version 6) was released in Sep. 2014, and GPM-GSMaP V04 (algorithm version 7) was released in Jan. 2017.
  - GPM-GSMaP V05 (algorithm version 8) will be released in July 2020.
  - Real-time version, GSMaP_NOW has been extended to the whole globe since Jun. 2019.

Updates on the realtime/near-realtime GSMaP

- Real-time version, GSMaP_NOW has been extended to the whole globe since Jun. 2019!

Nov.2015
Open to the public within Himawari region

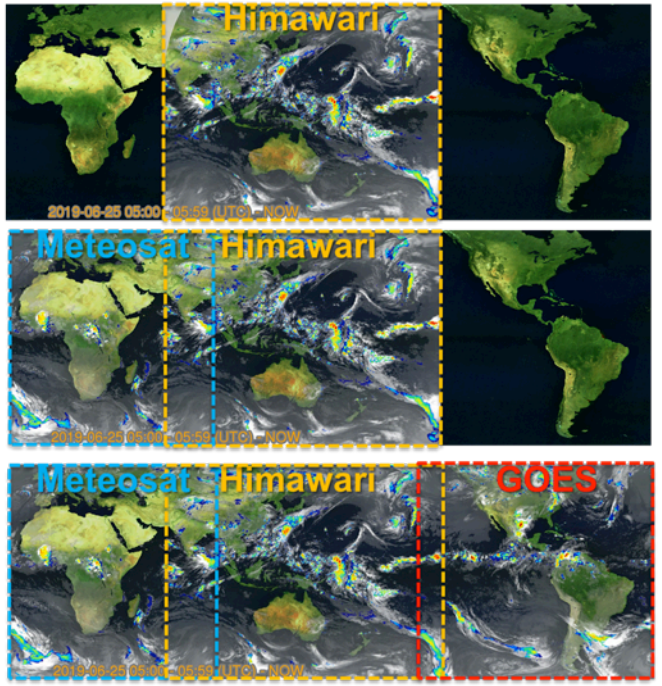
Data collection by the JAXA-EUMETSAT MOU

Nov.2018
Extended to Meteosat region

Data collection with the INPE, Chiba Univ. & JMA

Jun.2019
Extended to GOES region

=Whole globe Rainfall data is available in realtime!



Gauge-adjusted Realtime/Near-Realtime version is available!

- Improved NRT-basis Gauge-adjusted GSMaP product was open to the public in Dec. 2018.
  - Correction coefficients are calculated using past 30 days based upon Mega et al. (2019)'s method.
  - Long-term data since March 2000 is available from ftp site.
- Newly Gauge-adjusted GSMaP_NOW has been open to the public since Jun. 2019.
  - Correction method is mostly same as GSMaP_Gauge_NRT.

Contribution to WMO SEMDP

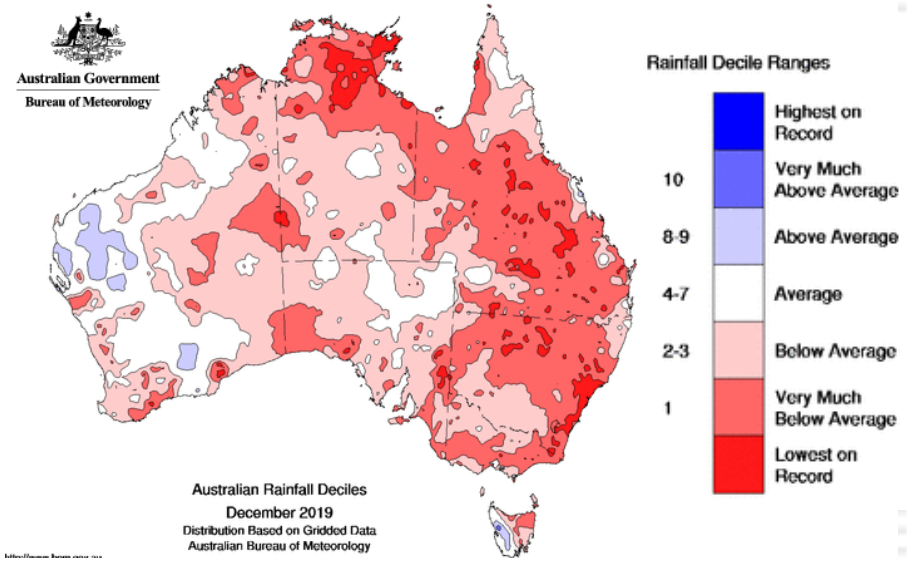
Space-based Weather and Climate Extremes Monitoring Demonstration Project

- WMO Space-based Weather and Climate Extremes Monitoring (SWCE… …stern Pacific… …2019, DOI:1…
- JAXA a… …NRT-basis G… …al.
- Target… …onth.

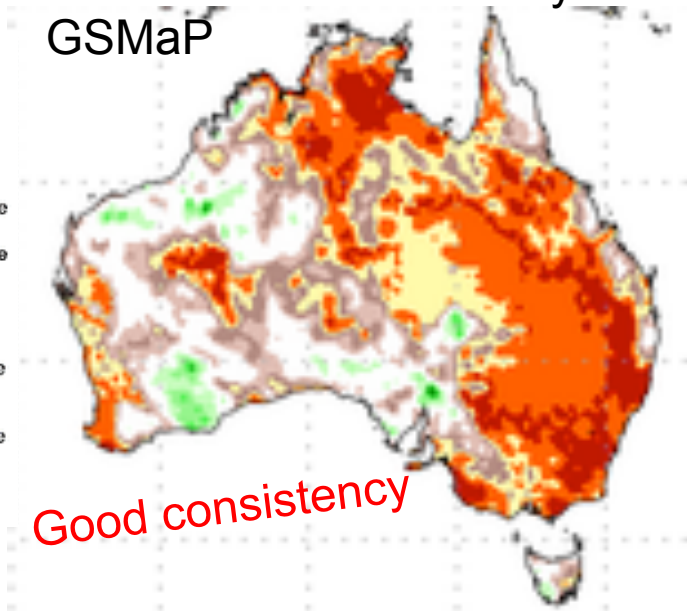
Spatial distribution of the anomaly from climate normal by approximately 20-year GSMaP data can help their decision making.

Case study for severe drought in Australia (Dec. 2019)

Reported by local Agency (BoM)



1-month SPI detected by GSMaP



http://www.bom.gov.au/jsp/awap/rain/index.jsp?colour=colour&time=latest&step=0&map=decile&period=month&area=nat

2nd Meeting of th…

http://www.wmo.int/pages/prog/sat/SEMDP/semdp_portal.html

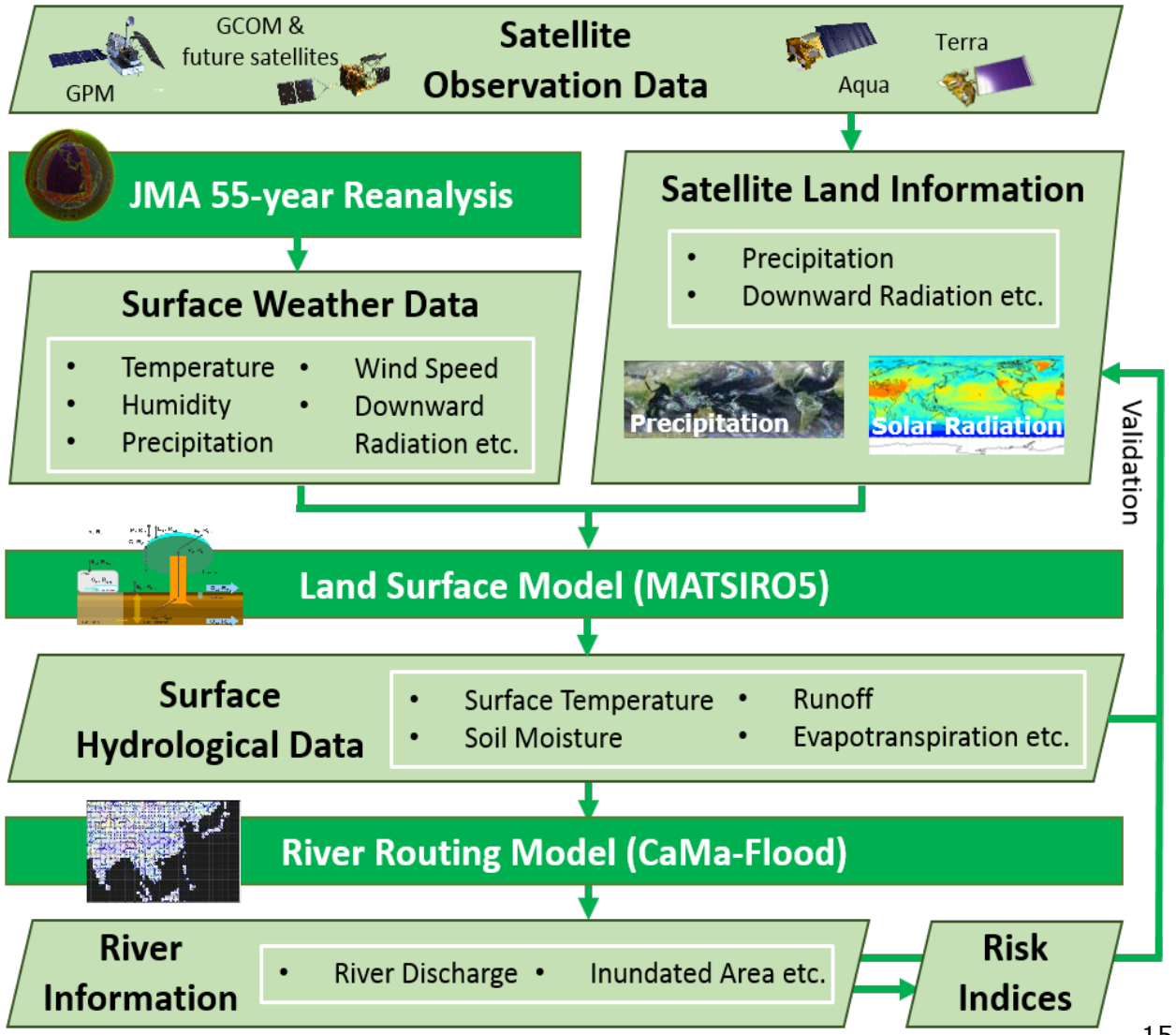
Global Hydrological Simulation System; Today's Earth

- JAXA has developed the global hydrological simulation system "Today's Earth" with satellite data as inputs under the joint research with the University of Tokyo
- Over 50 hydrological variables simulated through 3 different experiments (shown below) are now accessible through the web page and ftp site.
- Currently, 50km(land)/25km(river) resolution data for global coverage (TE-Global) and 1km resolution data for Japan area (TE-Japan) are available
- Collaboration with other models, atmospheric & ocean models, are underway.

Collaboration between JAXA and the Univ. of Tokyo

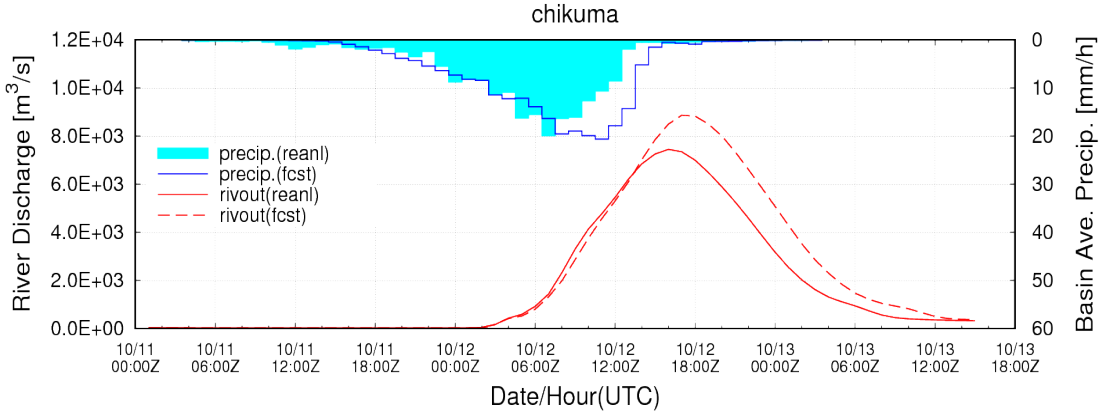
TODA'S EARTH
Land surface simulation by JAXA and UTokyo

https://www.eorc.jaxa.jp/theme/water/

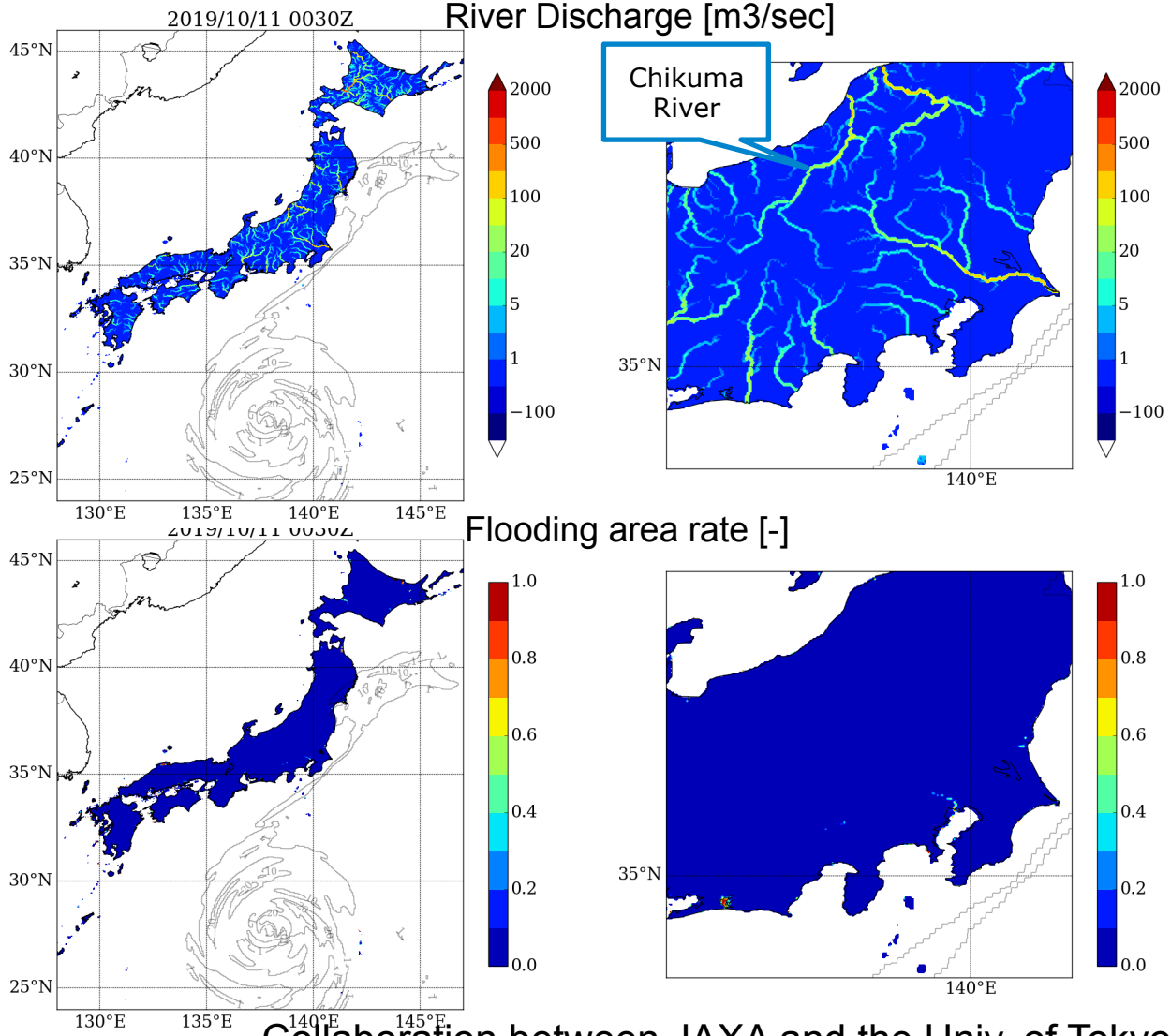


TE-Japan: Forecast experiment for Typhoon No.19 “Hagibis”

- Typhoon No.19 “Hagibis” (11 Oct. 2019-)
  - During 11-12 Oct., Typhoon No.19 hit Kanto and Tohoku area in Japan and caused serious damages in wide area.
  - TE-Japan’s forecast experiment from 10 Oct. (1-day before) showed it can alert in appropriate timing to wide area including Chikuma river where actual damages.
  - Comparison of output results by MSM forecast and analysis indicated that initial rise and peak of river discharge are simulated in almost same timing.



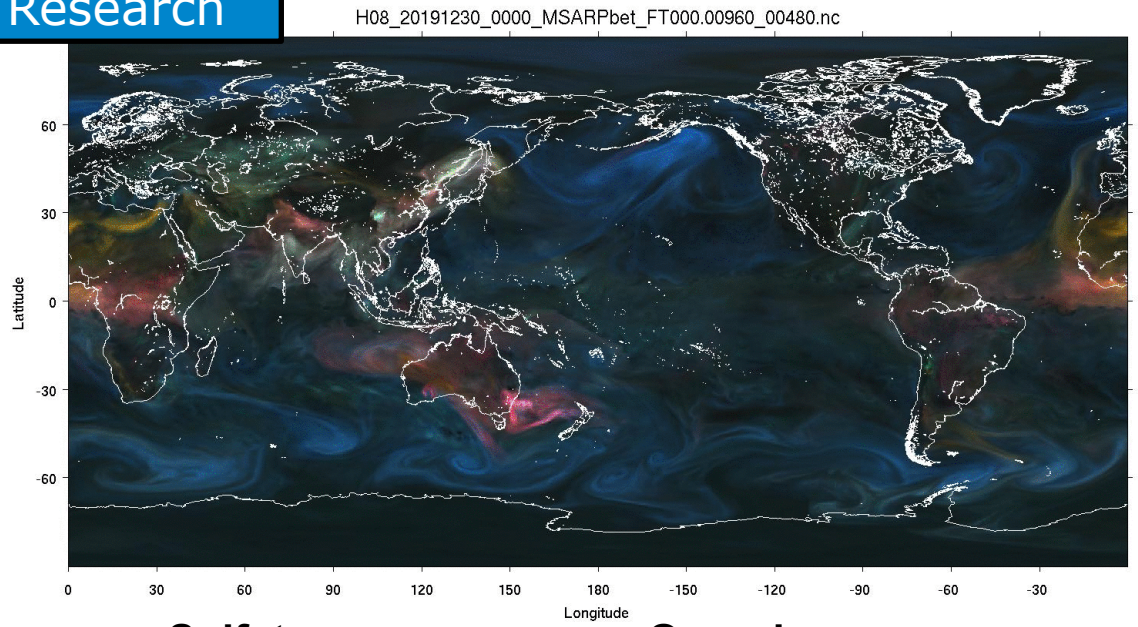
Forecast from 9JST Oct. 11, 2019 by TE-Japan

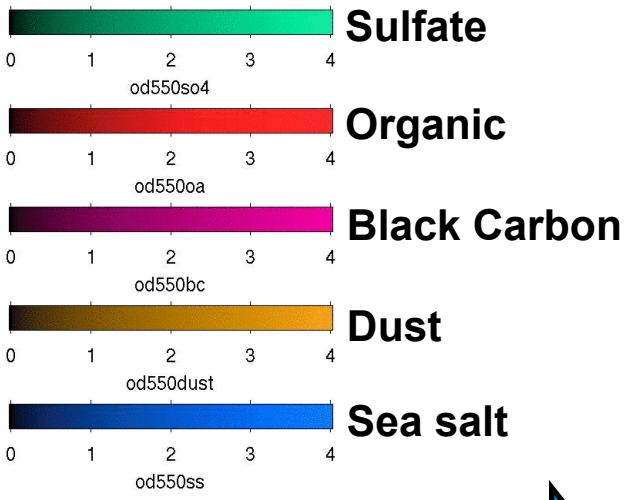


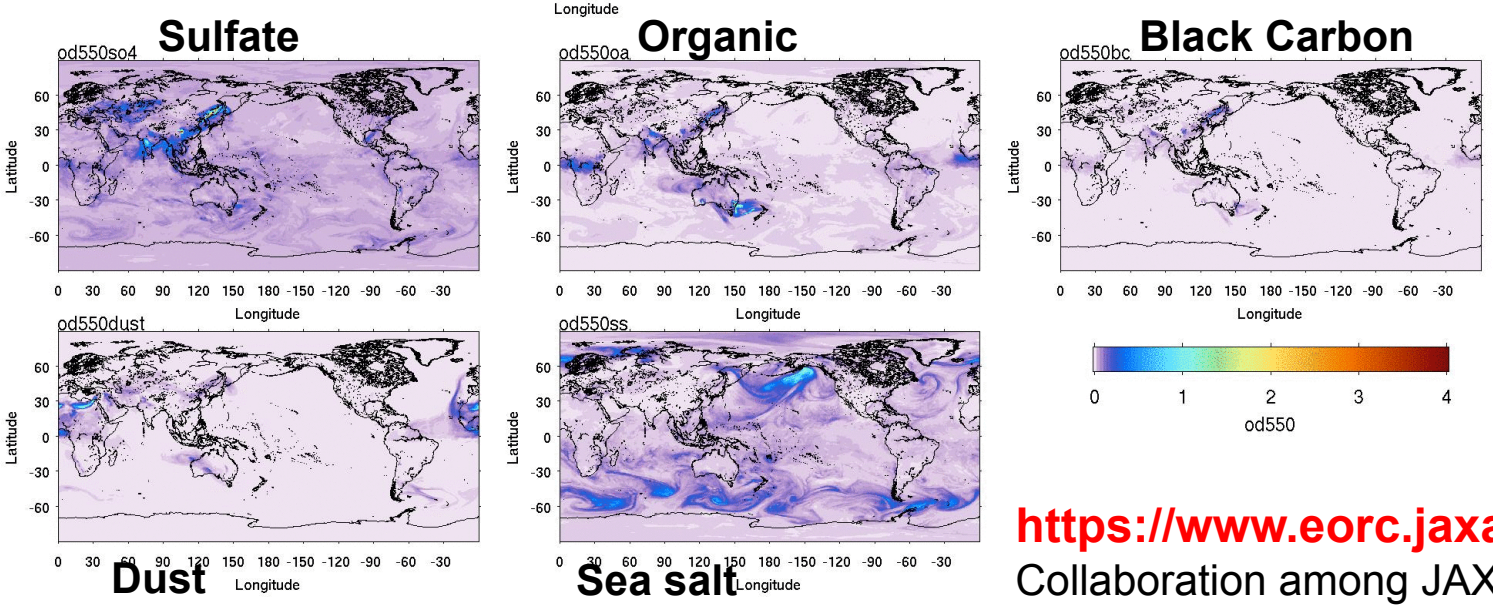
Collaboration between JAXA and the Univ. of Tokyo

Himawari Aerosol Assimilated to Model

Research







Operational

- ✓ JAXA has provided the Himawari aerosol algorithm (L2, L3) to JMA, and JMA has implemented the algorithm to its operational system
- ✓ JMA will start data assimilation of the Himawari aerosol in its **operational system from 29 Jan. 2020**.
- ✓ Data assimilation of aerosol by polar orbital satellites (e.g. GCOM-C/ SGLI) will be the next target.

https://www.eorc.jaxa.jp/ptree/

Collaboration among JAXA, JMA-MRI and Kyusyu Univ.

Summary

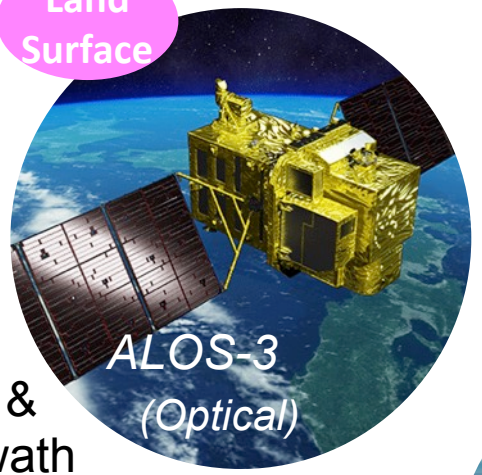
- Satellites
  - Nominal Operation: GCOM-C, GOSAT-2
  - Extended Operation: GOSAT, GCOM-W, GPM, ALOS-2
  - Future: ALOS-3 (JFY2020), ALOS-4 (JFY2021), EarthCARE (JFY2022), and GOSAT-GW (JFY2023)
  - Feasibility study: Next generation Precipitation Radar
- Researches
  - Development of Grand Plan for Water Cycle Observations by Satellites (in Japanese)
  - Several new data/web sites are available
    - SGLI, GOSAT-2, AMSR-E reprocessing, Himawari geophy
    - GSMaP realtime version (GSMaP_NOW) extended coverage to global
    - DPR's 3D rainfall view web site
    - TE-Japan (land simulation) in Japan area with 1-km resolution
  - Collaborations with WMO, JMA and other agency/institute/private company are ongoing

backup

Future JAXA's Earth Observation Satellites

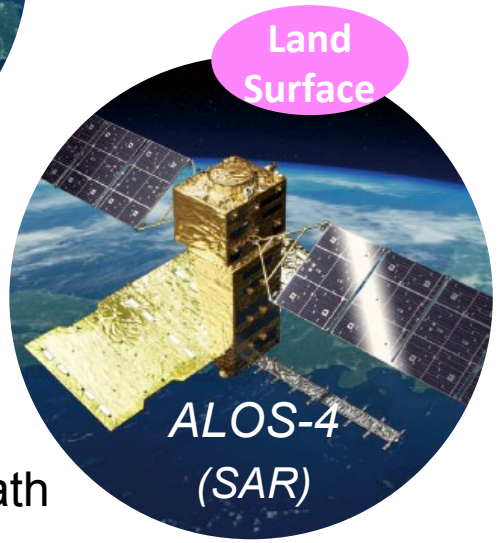
2020	2021	2022	2023
ALOS-3	*ALOS-4*	*EarthCARE*	*GOSAT-GW*

Land Surface



0.8m res. &
>70km swath

Land Surface

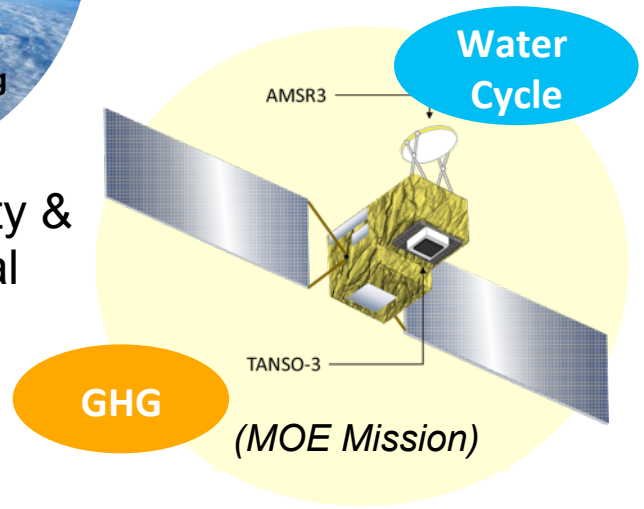


3m res. &
200km swath

Cloud/Aerosol Radiation Budget

Doppler capability &
vertical/horizontal
500m res.

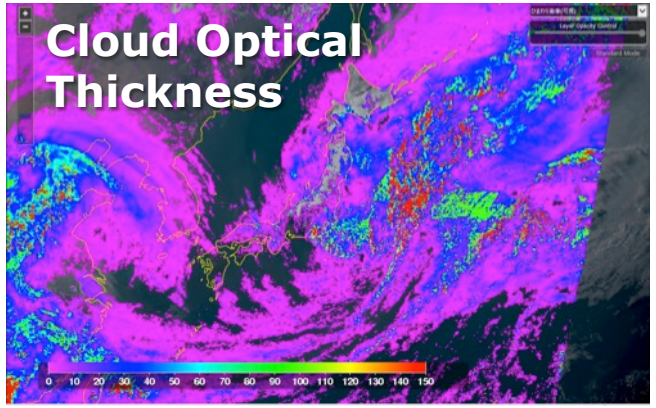
(JAXA Mission)

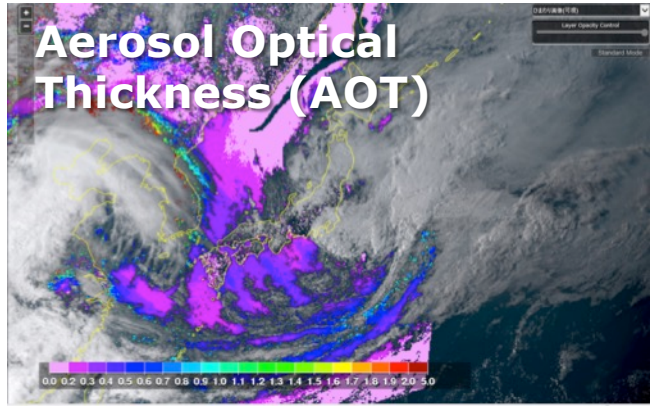


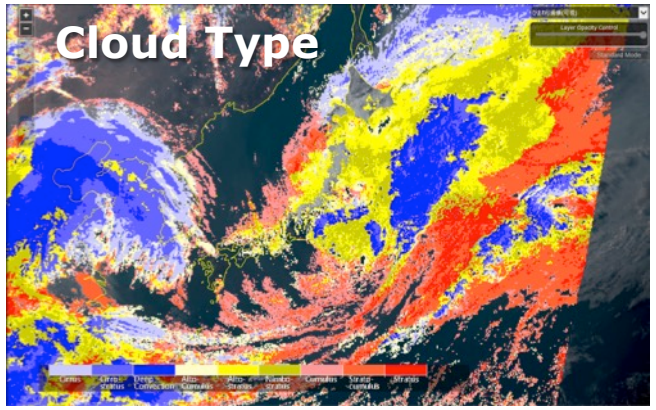
JAXA Himawari Level 2, 3 & 4 Products

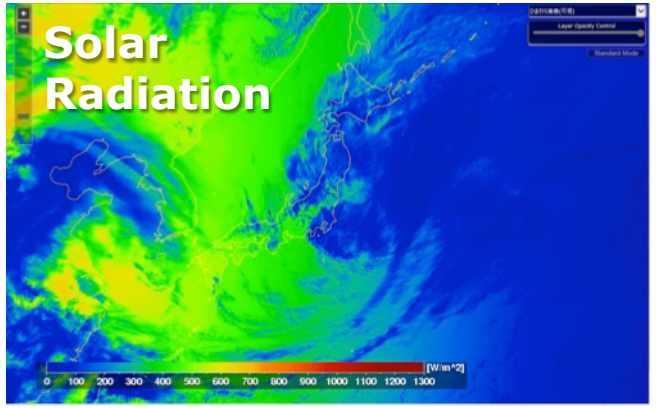
https://www.eorc.jaxa.jp/ptree/

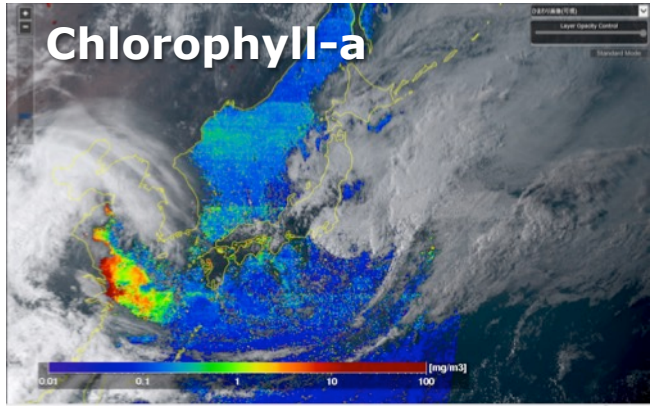
L2&L3

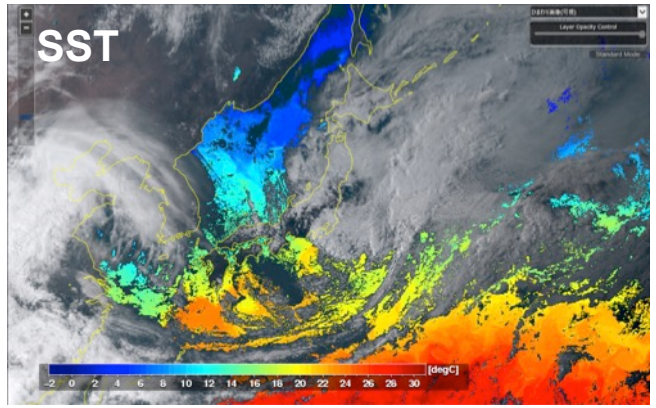




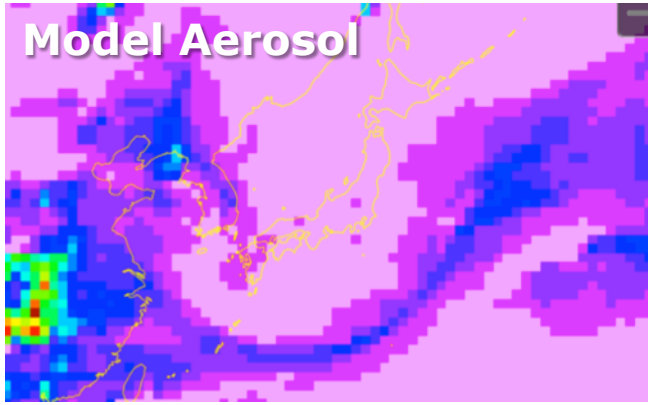


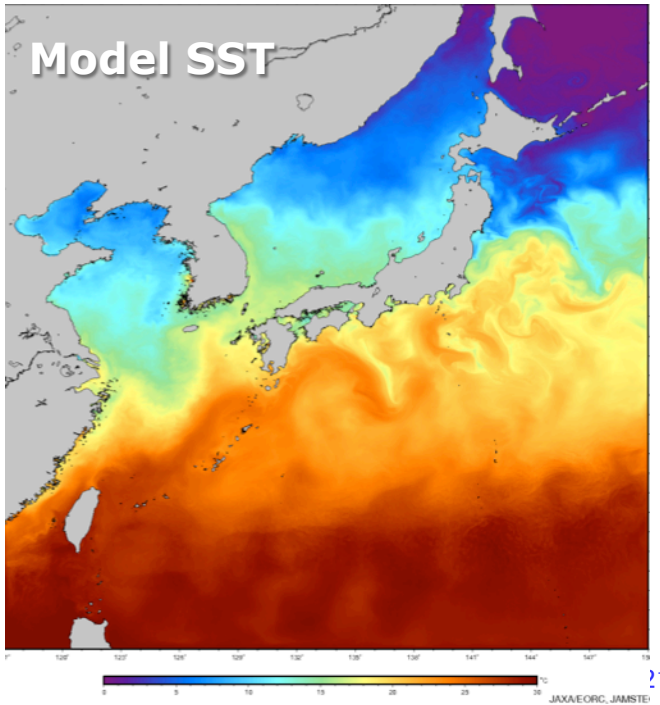






L4: NEW in 2018





JAXA's Open and Free EO Data and Services

	Portal Name and URL
	**G-Portal** Provides products of GPM, GCOM-W, GCOM-C, GOSAT, and Past Satellites and Sensors (MOS-1/1b, JERS-1, ADEOS, ADEOS-II, Aqua/AMSR-E, TRMM/PR) **https://gportal.jaxa.jp/gpr/** (Contacts : z-gportal-support@ml.jaxa.jp)
	**GSMaP: Global Satellite Mapping of Precipitation** Provides hourly Global Rainfall Map in Near-Real-Time (GSMaP_NRT), available four hours after observation. (GPM-Core GMI, TRMM TMI, GCOM-W1 AMSR2, DMSP series SSMIS, NOAA series AMSU, MetOp series AMSU, and Geostationary IR) **https://sharaku.eorc.jaxa.jp/GSMaP/** (Contacts : z-trmm_real@ml.jaxa.jp)
	**JAXA Himawari Monitor** Provides multi-satellite products from the Himawari Standard Data provided by the Japan Meteorological Agency (JMA) as well as the geophysical parameter data (Aerosol Optical Thickness, Sea Surface Temperature, Short Wave Radiation, Chlorophyll-a, Wild Fire, Photovoltaic Power, Cloud Optical Thickness and Cloud Type) produced by JAXA. **https://www.eorc.jaxa.jp/ptree/** (Contacts : z-ptree@ml.jaxa.jp)
	**GDAS: GOSAT Data Archive Service** **(Operated by National Institute for Environmental Studies (NIES))** Provides GOSAT products (Methane and CO2). **https://data2.gosat.nies.go.jp/index_en.html** (Contacts: gosat-support@nies.go.jp)

Status of collaboration with other space agencies

Agency	Collaboration
JMA	Data exchange, algorithm development, CAL/VAL, utilization in operational activities
NASA	Joint development/operation of GPM, CAL/VAL for GOSAT-1&2/OCO-2, A-CCP mission studies, collaboration in disaster monitoring
NOAA	GCOM-W&C&GOSAT-GW/JPSS collaboration, utilization in operational activities, GCOM-W data distribution to US agencies
ESA	Joint development of EarthCARE, collaboration in GHGs related missions
EUMETSAT	Data exchange, GCOM-W&Himawari (&C in future) data distribution to member countries via EUMETCast, partnership in GPM (MetOp)
DLR	Collaboration in Strategic Dialogue (EO sub working group consists of 6 themes), collaboration in GHGs related missions
CNES	Collaboration in GHGs related missions, partnership in GPM (Megha-Tropiques), ALOS-2/Sentinel-1 collaboration
CSA	Collaboration in disaster monitoring
ISRO	Collaboration in improvement/validation of rainfall products, partnership in GPM (Megha-Tropiques)

23