



GSMaP
GLOBAL SATELLITE MAPPING OF PRECIPITATION

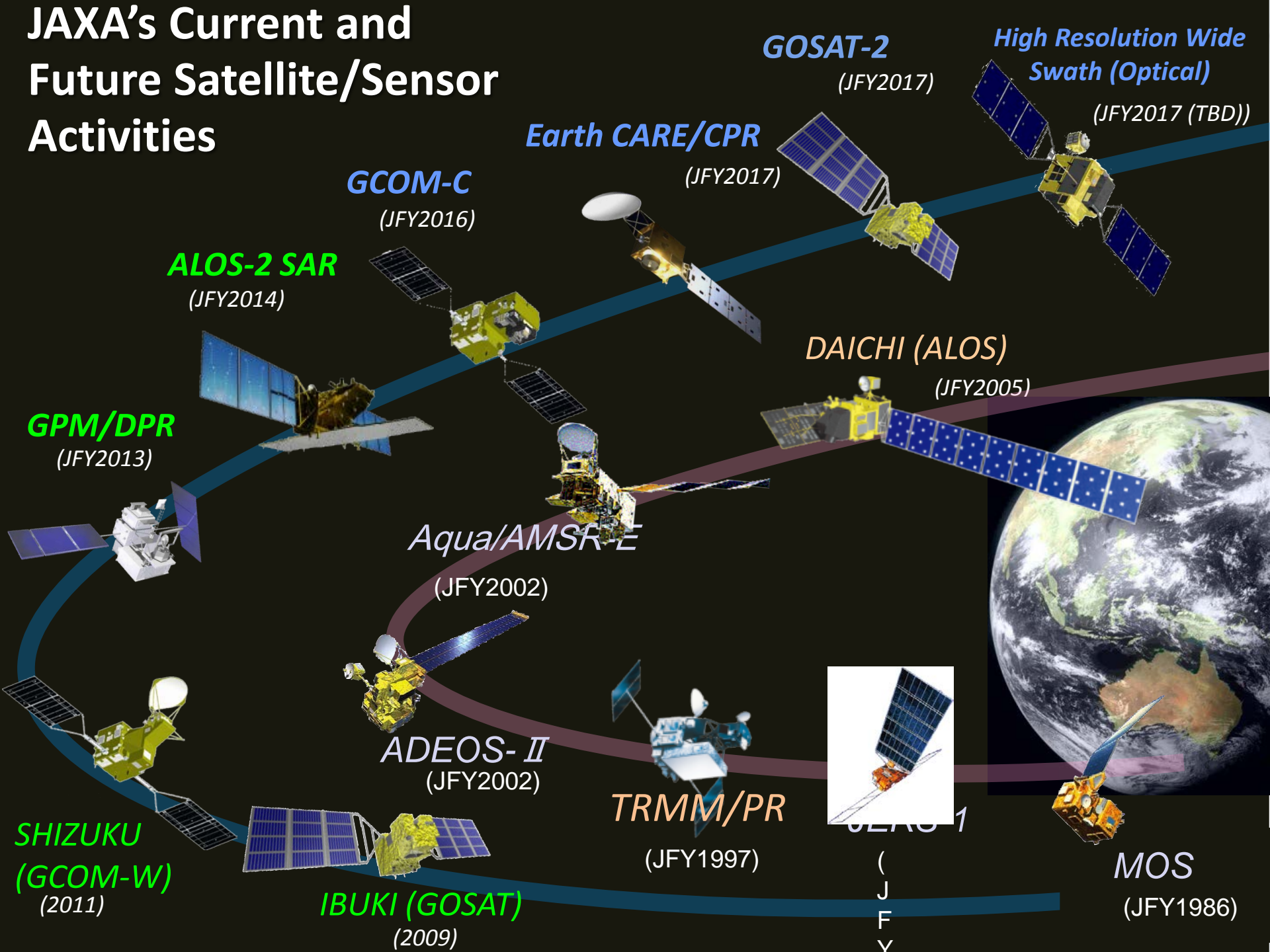
Real-time Global Satellite Mapping of Precipitation (GSMaP) product

Riko Oki

**Earth Observation Research Center (EORC)
Japan Aerospace Exploration Agency (JAXA)**



JAXA's Current and Future Satellite/Sensor Activities





内閣府戦略室宇宙基本計画 工程表(情報収集関係)

2015 2020 2025 2030 2034

		2015年度	2016年度	2017年度	2018年度	2019年度	2020年度	2021年度	2022年度	2023年度	2024年度	2025年度	2026年度	2027年度	2028年度	2029年度	2030年度	2031年度	2032年度	2033年度	2034年度		
		27年度	28年度	29年度	30年度	31年度	32年度	33年度	34年度	35年度	36年度	37年度	38年度	39年度	40年度	41年度	42年度	43年度	44年度	45年度	46年度		
情報収集衛星 光学	光学4号機(2011年度打ち上げ)																						
	光学5号機(2014年度打ち上げ)																						
	光学6号機																						
	光学7号機(光学5号機の後継機)																						
	光学8号機(光学6号機の後継機)																						
	光学9号機(光学7号機の後継機)																						
	光学10号機(光学8号機の後継機)																						
	光学11号機(光学9号機の後継機)																						
	光学12号機(光学10号機の後継機)																						
	光学13号機(光学11号機の後継機)																						
	●継続的に開発・運用等																						
	情報収集衛星 レーダ	レーダ3号機(2011年度打ち上げ)																					
		レーダ4号機(2012年度打ち上げ)																					
レーダ予備機(2014年度打ち上げ)																							
レーダ5号機																							
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レーダ12号機(レーダ10号機の後継機)																							
●継続的に開発・運用等																							

情報収集衛星光学

情報収集衛星レーダ



内閣府戦略室宇宙基本計画 工程表(だいち/ひまわり/いぶき)

		2015年度	2016年度	2017年度	2018年度	2019年度	2020年度	2021年度	2022年度	2023年度	2024年度	2025年度	2026年度	2027年度	2028年度	2029年度	2030年度	2031年度	2032年度	2033年度	2034年度		
		27年度	28年度	29年度	30年度	31年度	32年度	33年度	34年度	35年度	36年度	37年度	38年度	39年度	40年度	41年度	42年度	43年度	44年度	45年度	46年度		
陸域 海域 陸域・海域観測	先進光学衛星						先進光学衛星							先進光学衛星後継機①									
																					先進光学衛星後継機②		
																						●継続的に開発・運用等	
	陸域観測技術衛星(だいち2号 2014年度打ち上げ)																						
	先進レーダ衛星						先進レーダ衛星(だいち2号後継機)							先進レーダ衛星後継機①									
																						先進レーダ衛星後継機②	
																						●継続的に開発・運用等	
気象 気象観測	静止気象衛星	ひまわり6号(待機運用)		ひまわり7号(待機運用)		ひまわり8号(2014年度打ち上げ)		ひまわり9号(待機運用)		以後、ひまわり8号に替えて観測運用										待機			
																						待機	
																						●継続的に製造・運用等	
温室効果ガス	温室効果ガス観測技術衛星	いぶき(Ibuki)										温室効果ガス観測技術衛星3号機										●継続的に開発・運用等	
その他のリモートセンシング及びセンサ等技術の高度化	水循環	水循環変動観測衛星(しずく 2012年度打ち上げ)																					
	雲・植生	気候変動観測衛星(GCOM-C)																					
	降水	全球降水観測計画/二周波降水レーダ(GPM/DPR 2013年度打ち上げ)																					
	雲・エアロゾル	雲エアロゾル放射ミッション/雲プロファイリングレーダ(Earth CARE/CPR)																					
	超低高度衛星	超低高度衛星技術試験機(SLATS)																					
	低コスト小型衛星	アスナロ1号(2014年度打ち上げ)																					
		アスナロ2号																					
	センサ技術	ハイパースペクトルセンサ																					

だいち(Daichi)

ひまわり(Himawari)

いぶき(Ibuki)

←その他???(Others???)



年度	平成 27年度 (2015年度)	平成 28年度 (2016年度)	平成 29年度 (2017年度)	平成 30年度 (2018年度)	平成 31年度 (2019年度)	平成 32年度 (2020年度)	平成 33年度 (2021年度)	平成 34年度 (2022年度)	平成 35年度 (2023年度)	平成 36年度 (2024年度)	平成 37年度 以降
その他リモートセンシング衛星開発・センサ技術高度化(1/2)	その他リモートセンシング衛星の開発、センサ技術の高度化等の検討 [総務省、外務省、文部科学省、経済産業省、国土交通省、環境省]										
	水循環変動観測衛星(GCOM-W) [文部科学省]										
	運用					その他の明日は??					
	気候変動観測衛星(GCOM-C) [文部科学省]										
	開発			運用							
	打ち上げ▲										
	全球降水観測計画/二周波降水レーダ(GPM/DPR) [総務省、文部科学省]										
	運用										
雲プロファイリングレーダ(CPR) [総務省、文部科学省]											
開発			雲エアロゾル放射ミッション(EarthCARE) [ESAが打ち上げ担当のプロジェクト] ▲打ち上げ								
ESA引渡し▲											
超低高度衛星技術試験機(SLATS) [文部科学省]											
開発			運用								
打ち上げ▲											

2020(平成32)年度以降地球観測衛星計画が空白

※後期運用は衛星等が運用可能な限り継続

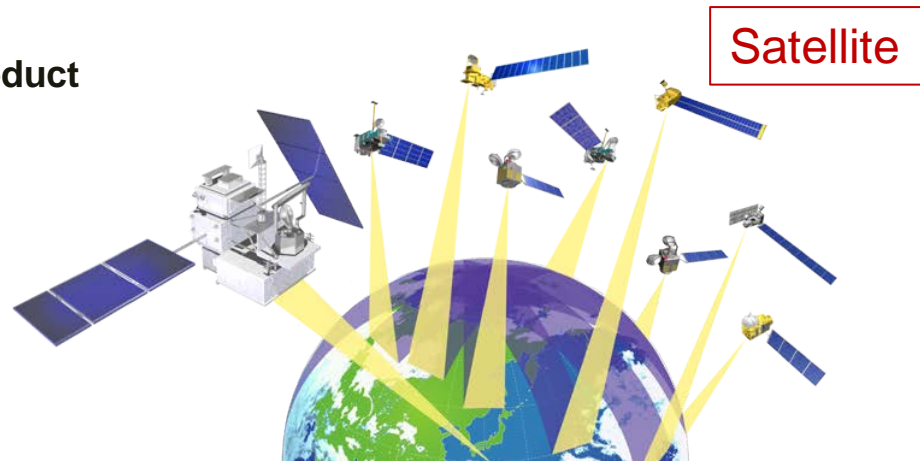
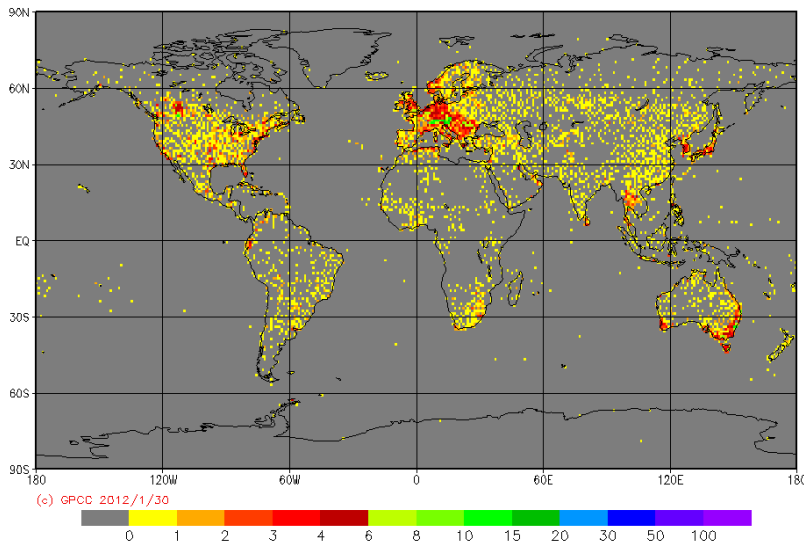
Precipitation observation from Space



- Precipitation affects most everyone's life & work, but is one of hardest meteorological parameters to measure;
 - because of its high spatial and temporal variability; and
 - most of ground observations are performed at urban area, and few observation over the ocean, deserts and mountainous areas

Distribution of rain gauge in GPCP Monitoring Product
Provided by Global Precipitation Climatology Centre (GPCC)
<http://gpcc.dwd.de>

GPCC Monitoring Product Gauge-Based Analysis 1.0 degree
number of stations per grid for October 2011

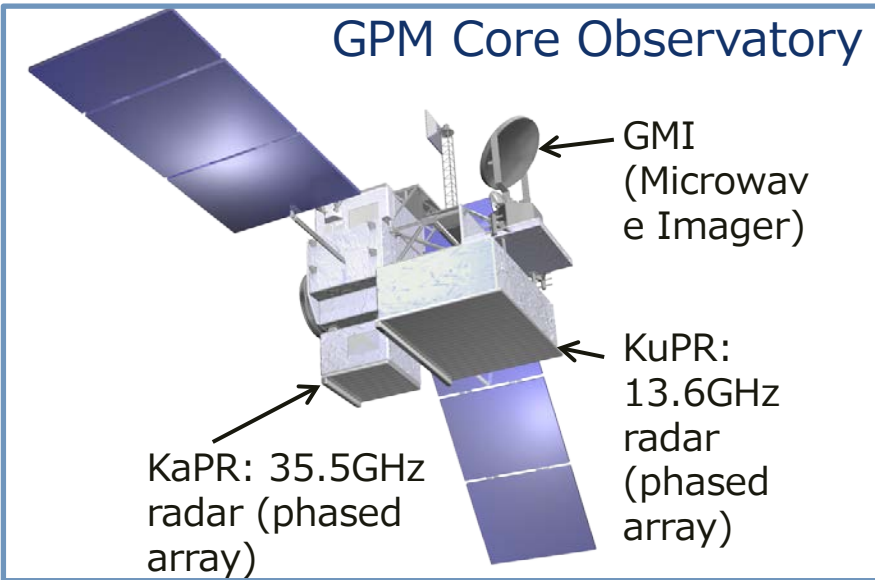


Merits of Satellite
Global observation
with the same time interval
with the same accuracy

Global Precipitation Measurement (GPM)



GPM Core Observatory



- GPM is an international mission consisting of the GPM Core Observatory and Constellation Satellites for high accurate and frequent global precipitation observation.

- Core Observatory: developed under NASA and JAXA equal partnership.
- Constellation satellites: provided by international partners (includes GCOM-W1).

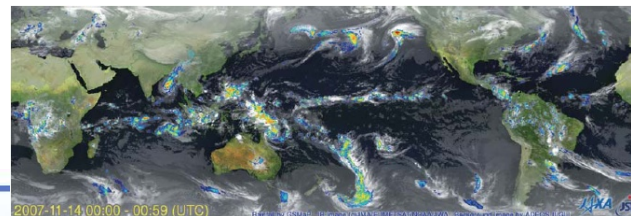
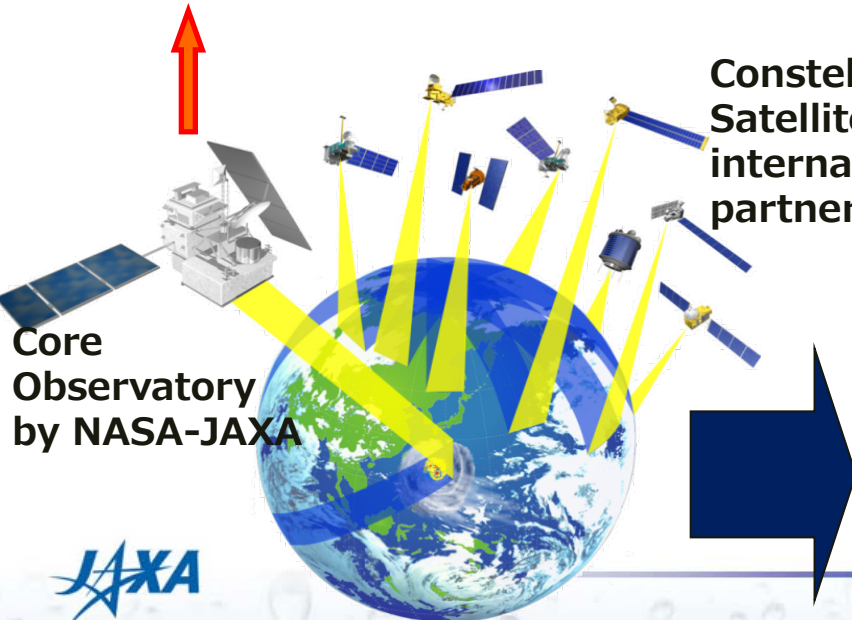
■ Dual-frequency Precipitation Radar (DPR)

- developed by JAXA and NICT
- DPR is composed of two radars: KuPR & KaPR

- GPM Core Observatory was successfully launched **on 28 Feb. 2014 (JST)**.

- All GPM standard products were released on September 2014.

Constellation Satellites by international partners

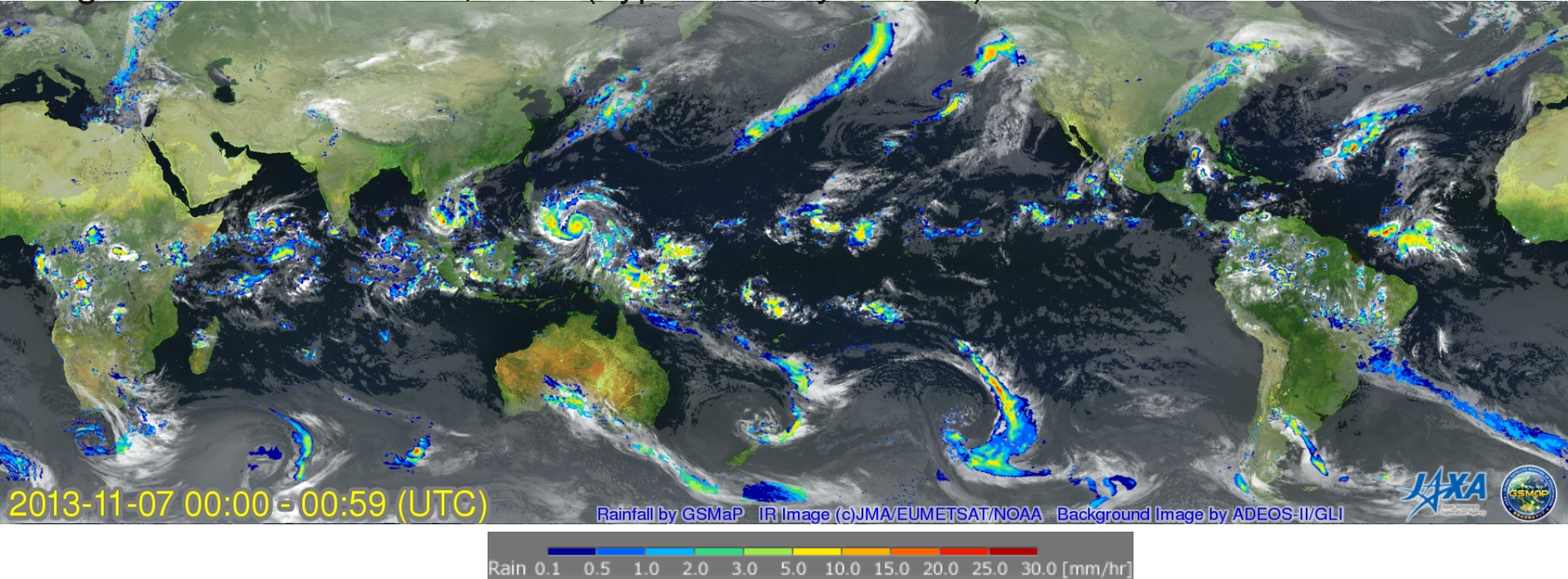


Global Satellite Mapping of Precipitation (GSMaP)

<http://sharaku.eorc.jaxa.jp/GSMaP/>



A figure on 7th November, 2013 (Typhoon Haiyan case)



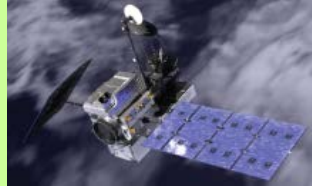
- GSMaP is a blended Microwave-IR product and has been developed in Japan for the GPM mission.
 - Processing and distributing global rainfall data in near real time basis (about 4-hour after observations) by merging multi-satellite data.
 - Hourly product in 0.1x0.1deg. lat/lon grid.
- Proto-type version has been in operation in JAXA since 2007.
 - "GPM-GSMaP" data were released on Sep. 2014.



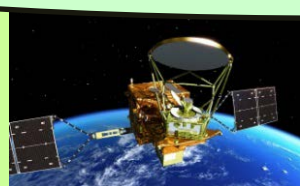
Overview of GSMaP Algorithm



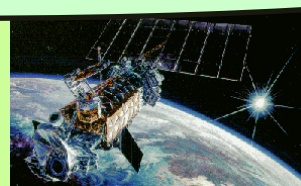
Microwave Imagers & Sounders



**GPM-Core
GMI**



**GCOM-W
AMSR2**



**DMSP
SSM/I, SSMIS**



**NOAA/MetOp
AMSU**

Good: high-frequent
(wide swath, multi-satellites)
Bad: cannot
measure vertical
structure (need info.
from radar)

**GSMaP Microwave Radiometer
Retrieval Algorithm**

**Rainfall Data from each
Microwave Radiometer**

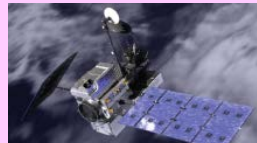
**Merged Microwave
Rainfall Data**

**Precipitation
Radars**



**TRMM
PR**

**Data
Base**



**GPM-Core
DPR**

**IR
Imagers**



**Geostationary
Satellites**

**Microwave-IR Merged
Algorithm (CMV, K/F)**

**Global Rainfall Map
+ Gauge-calibrated
Rainfall Map
(0.1 degree grid, Hourly)**

*(Okamoto et al. 2005, Kubota et al, 2007,
Aonashi et al. 2009, Ushio et al. 2009,
Shige et al. 2009, Kachi et al. 2011)*



GPM-GSMaP Product list



Standard product (Latency: 3 days)

Product name	Variables	Horizontal resolution	Temporal resolution	Latency	Correction
L3 GSMaP Hourly	Hourly Precip Rate (GSMaP_MVK)	0.1×0.1 deg.lat/lon	1 hour	3 days	None
	Gauge-corrected Hourly Precip Rate corrected by gauge (GSMaP_Gauge)				Corrected by daily rain gauges (NOAA CPC Gauge-Based Analysis, Chen et al. 2008)

Near-real-time product (Latency: 4 hours)

Product name	Variables	Horizontal resolution	Temporal resolution	Latency	Correction
L3R GSMaP Hourly	Hourly Precip Rate (GSMaP_NRT)	0.1×0.1 deg.lat/lon	1 hour	4 hours	None
	Gauge-corrected Hourly Precip Rate corrected by gauge (GSMaP_Gauge_NRT)				Correction by empirical coefficients

GPM-GSMaP data is now available from JAXA G-portal (<https://www.gportal.jaxa.jp>)

➤ as well as current GSMaP web site (<http://sharaku.eorc.jaxa.jp/GSMaP/>).

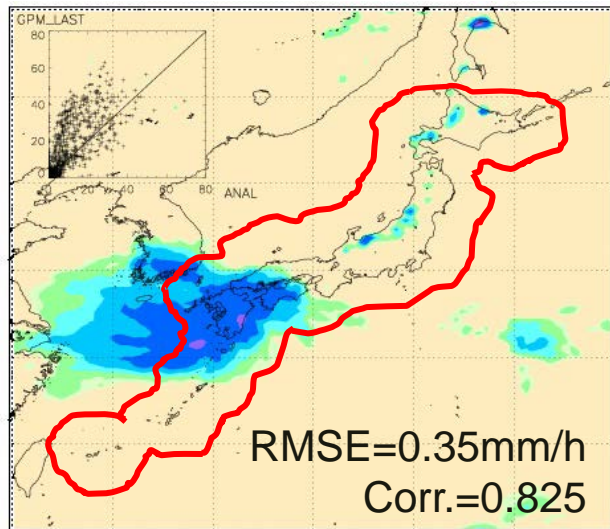
Evaluation of GPM-GSMaP



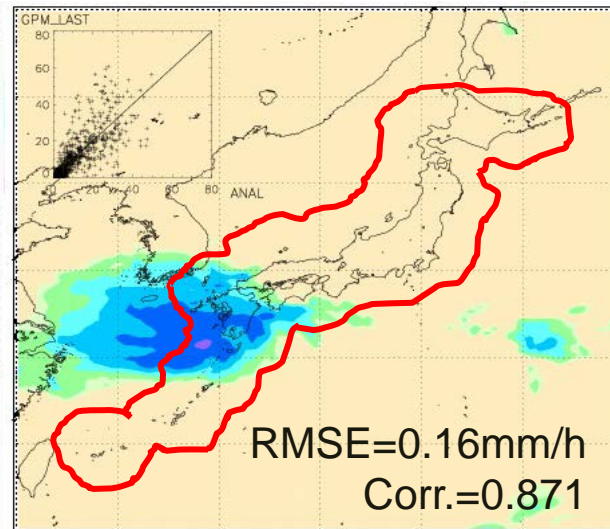
- Daily averaged rainfall around Japan in 0.25 degree grid was compared with JMA's Radar-AMeDAS (gauge-calibrated radar analysis rainfall).

An example on Apr. 12, 2014

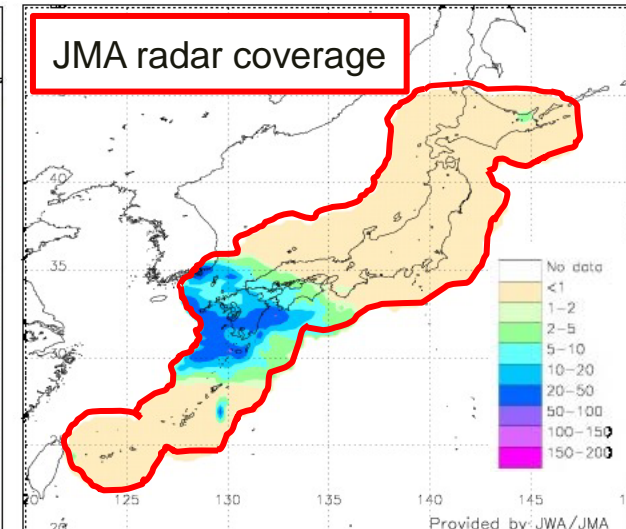
GSMaP_MVK



GSMaP_Gauge



Gauge-Radar Analysis



→ **GSMaP_Gauge** shows better correlation with less Root Mean Square Error (RMSE) on Apr. 12, 2014.



IPWG Validation collaboration

- The GSMAp joins the International Precipitation Working Group (IPWG) validation activities.
- Within IPWG Validation collaboration framework, our GSMAp products are validated also in U.S. (J.-J. Wang/J. Janowiak), Australia (E. Ebert), South America (D. Vila), Europe (C. Kidd), and South Africa (E. Becker).

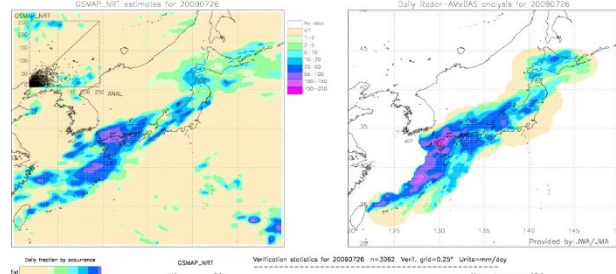
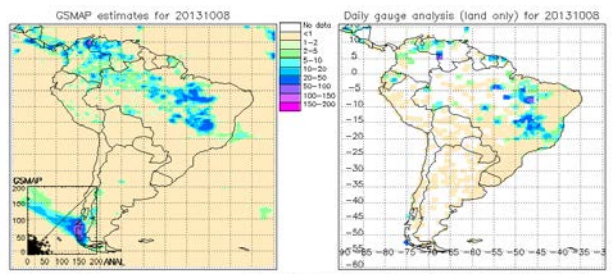
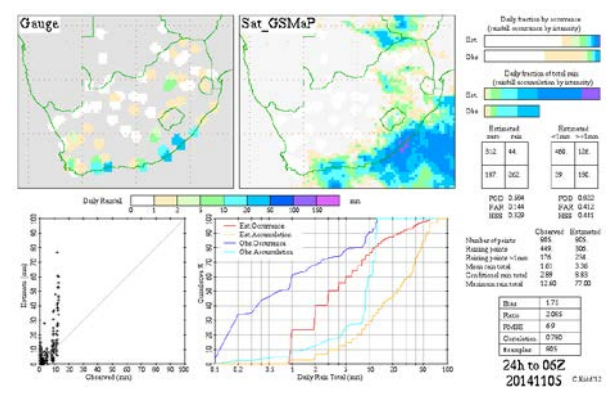
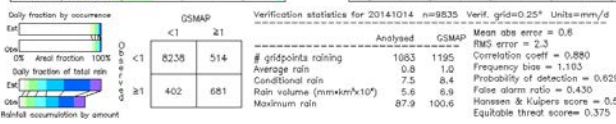
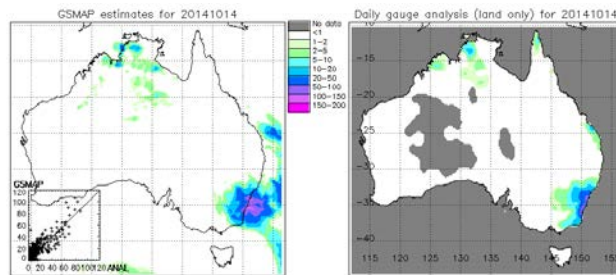
<http://cawcr.gov.au/projects/SatRainVal/validation-intercomparison.html>

13Z 09Nov2014 thru 12Z 10Nov2014
Data on 0.25 deg grid (UNITS are mm/day)

	(G) gauge	(S) GSMAp	(R) radar
Number of points:	12116	12116	12116
# points w/ rain:	1992	2159	768
Mean rain rate:	1.00	1.21	0.19
Cond. rain rate:	5.76	6.76	2.84
Max. rain rate:	43.01	41.47	15.43

	G-S	G-R	R-S
Correlation:	0.665	0.443	0.456
Mean Absolute Error:	1.03	0.87	1.09
RMSE (mm/day):	2.93	2.93	3.67
RMSE (normalized):	2.94	2.94	16.12
Probability of detection:	0.716	0.351	0.777
False Alarm Ratio:	0.340	0.112	0.716
Bias Ratio (rain to rain):	1.084	0.386	2.736
Heldreth Skill Score:	0.623	0.453	0.353
Hansen-Kuipers Score:	0.643	0.343	0.639
Equitable Threat Score:	0.452	0.292	0.215

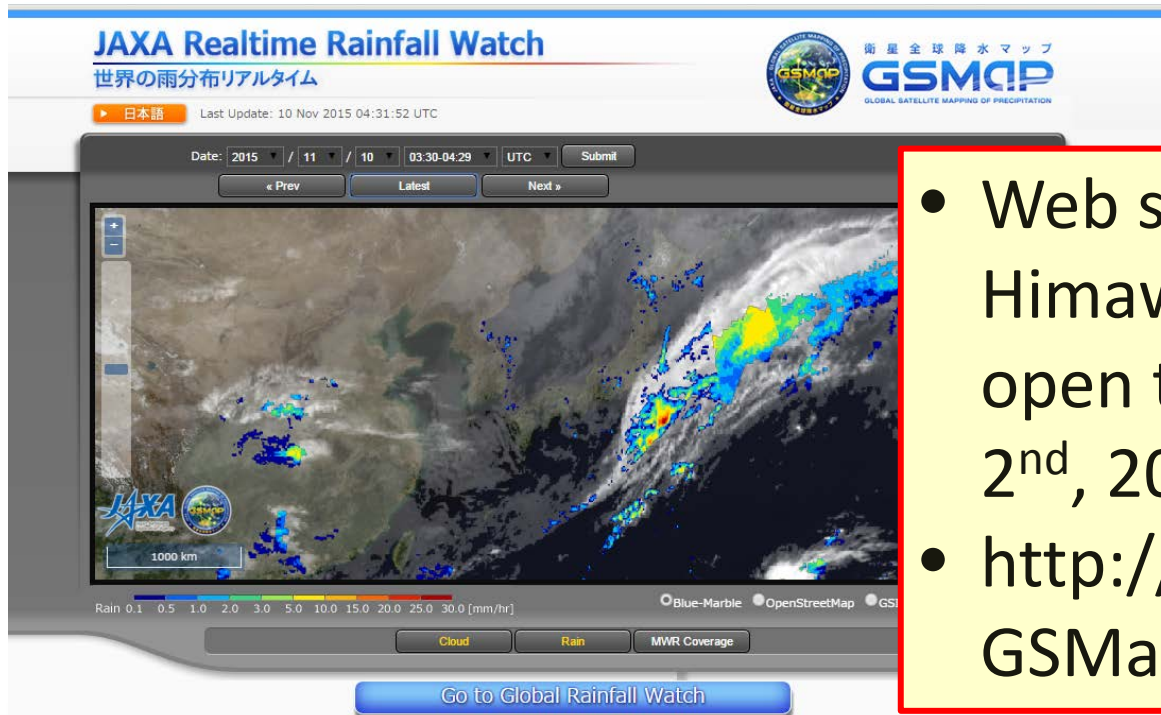
GSMAp		radar	
< 1	≥ 1	< 1	≥ 1
gauge	9391, 733	gauge	10038, 89
	≥ 1566, 1426		≥ 1292, 700



Development of GSMaP just now version (GSMaP_NOW)



- To reduce latency from 4-hr to “now”
 - Using data that is available within 0.5-hour (GMI, AMSR2 direct receiving data, AMSU direct receiving data and Himawari-IR) to produce GSMaP at 1-hr before (observation).
 - Applying 0.5-hour forward extrapolation (future direction) by cloud motion vector to produce GSMaP at current hour (just now).



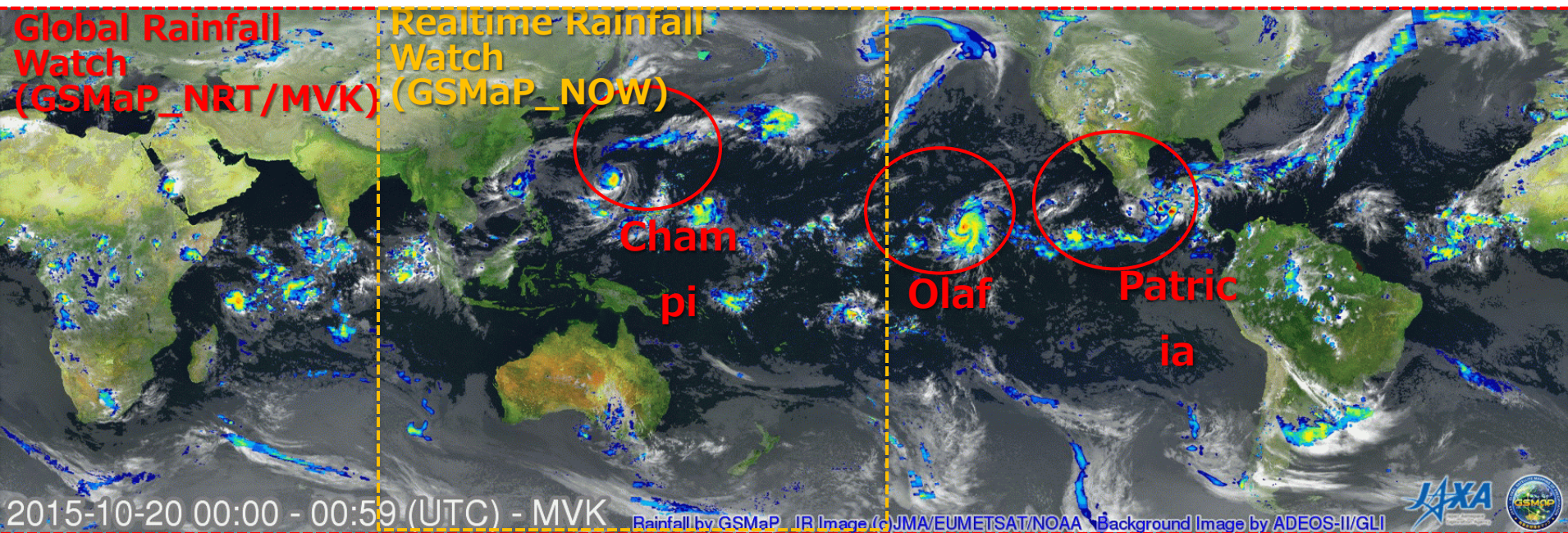
- Web site and data (GEO-Himawari region) are now open to the public on Nov. 2nd, 2015.
- http://sharaku.eorc.jaxa.jp/GSMaP_NOW/index_j.htm





“GSMaP_NOW” over “Himawari-8” area started!

Global Satellite Mapping of Precipitation (GSMaP)



GSMaP (Global) observed Hurricane Patricia and Olaf, and Typhoon Champi: 20-24 Oct. 2015, hourly animation

- **Rapidly changing precipitation phenomena need frequent observations.**

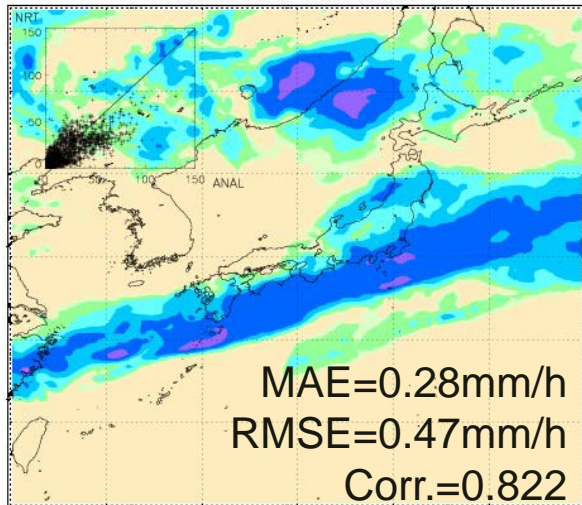
JAXA Global Rainfall Watch (4-hr delay) : <http://sharaku.eorc.jaxa.jp/GSMaP>
JAXA Realtime Rainfall Watch (Himawari-area):
http://sharaku.eorc.jaxa.jp/GSMaP_NOW

Early Evaluation of GSMaP_NOW



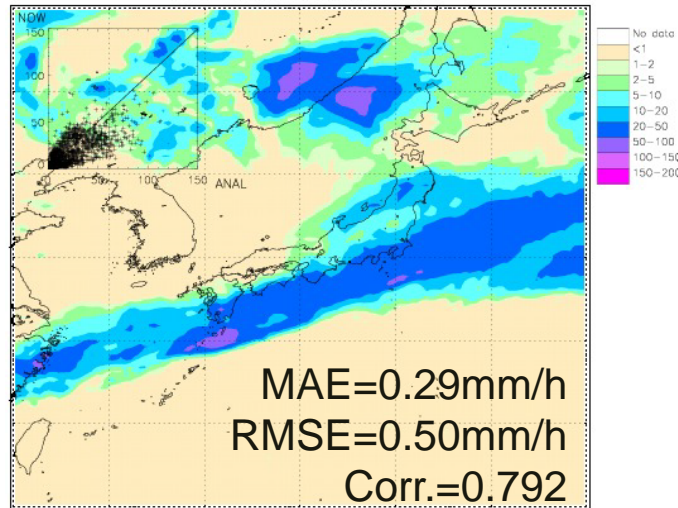
GSMaP_NRT

NRT estimates for 20150701



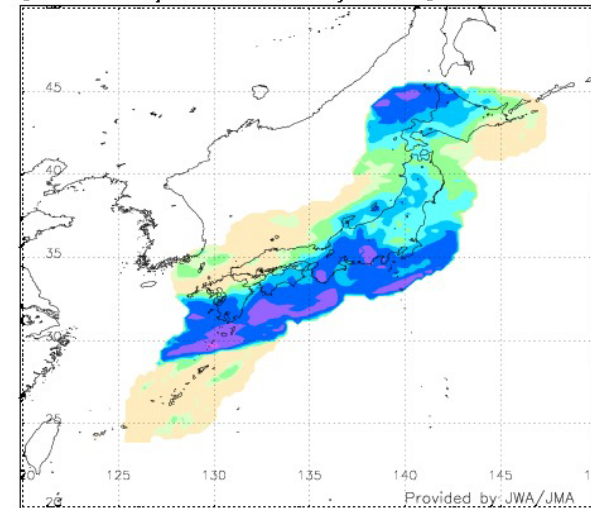
GSMaP_NOW

NOW estimates for 20150701



Gauge-Radar Analysis (Radar-AMeDAS)

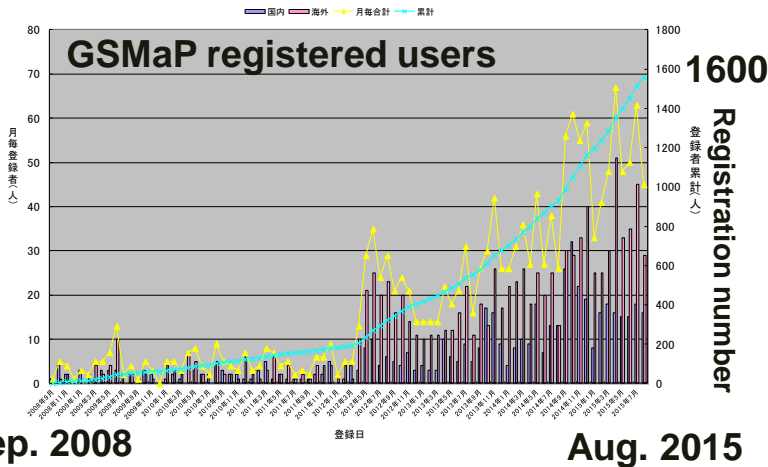
Daily Radar-AMeDAS analysis for 20150701



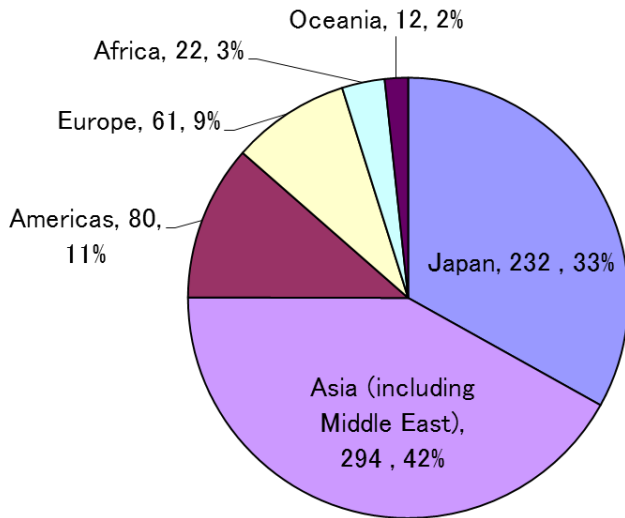
Daily averaged rainfall on Jul. 1, 2015

Period	Mean ABS Error (mm/h)		RMS Error (mm/h)		Correlation Coefficient	
	NRT	NOW	NRT	NOW	NRT	NOW
Jun. 11 – Jul. 3, 2015	0.22	0.24	0.52	0.56	0.786	0.756

GSMaP Applications



About 1600 registered users as of 31 Aug. 2015



About 67% users are originated from foreign countries.



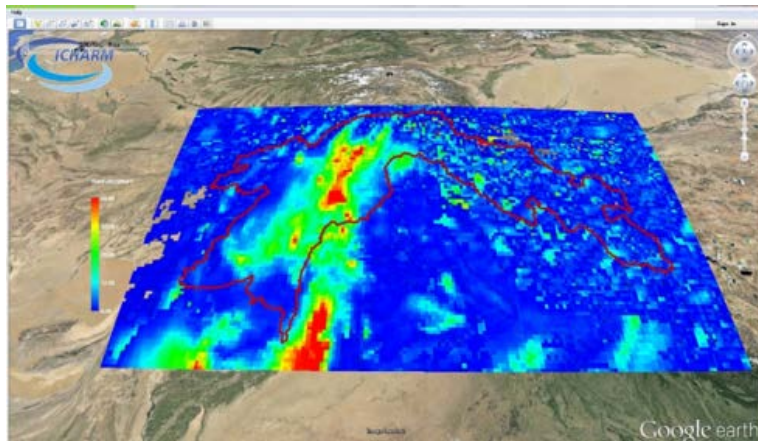
- Weather forecast/monitoring
 - Japan Weather Association (JWA) : Mobile phone, weather information
 - Meteorological agencies in Asian country: Rainfall monitoring, typhoon monitoring, flood prediction
- Flood warning/prediction
 - International Flood Network (IFNet), Infrastructure Development Institute (IDI) : Global Flood Alert System (GFAS)
 - International Centre for Water Hazard and Risk Management (ICHARM) : Integrated Flood Analysis System (IFAS)
 - Japan Water Association : flood potential monitoring
 - UNESCO-IHP: flood warning system using IFAS
 - Asia Development Bank (ADB): River management including flood risk
 - Japan International Cooperation Agency (JICA): Water resource management in river-basin, flood monitoring
- Agriculture/Industry/Education
 - Crop forecast, food security, weather index insurance
 - Providing precipitation and flood information to factories abroad
 - Using global rainfall map in educational materials

GSMaP in Flood Analysis with ICHARM



- Under UNESCO-IHP project, JAXA and ICHARM is developing with Pakistan Meteorological Department (PMD) to develop operational flood analysis system.
- After calibration of GSMaP product with ground-based stations in Pakistan, correlation coefficients are increased from 0.5 to 0.7, and can be used in the Indus Integrated Flood Analysis System (Indus-IFAS) developed by ICHARM.
- The system will be in operation in 2015 by PMD, and plan to extend the system to larger regions is underway.
- Similar system is in operation in Bangladesh and Philippines under ADB project.

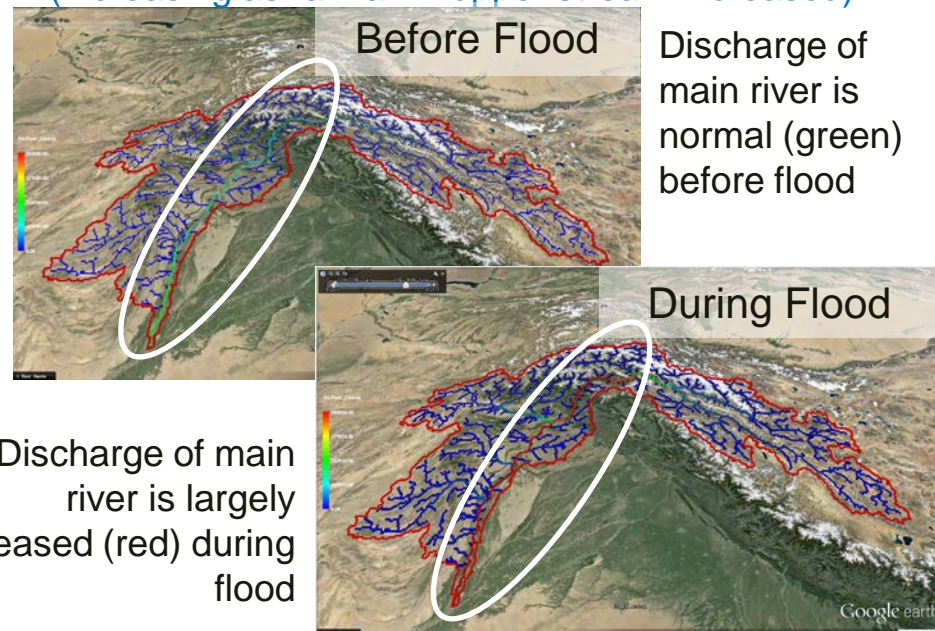
Rainfall by GSMaP



(Area within red line is Indus river basin)

River discharge output using GSMaP (increasing as rainfall in upper stream increased)

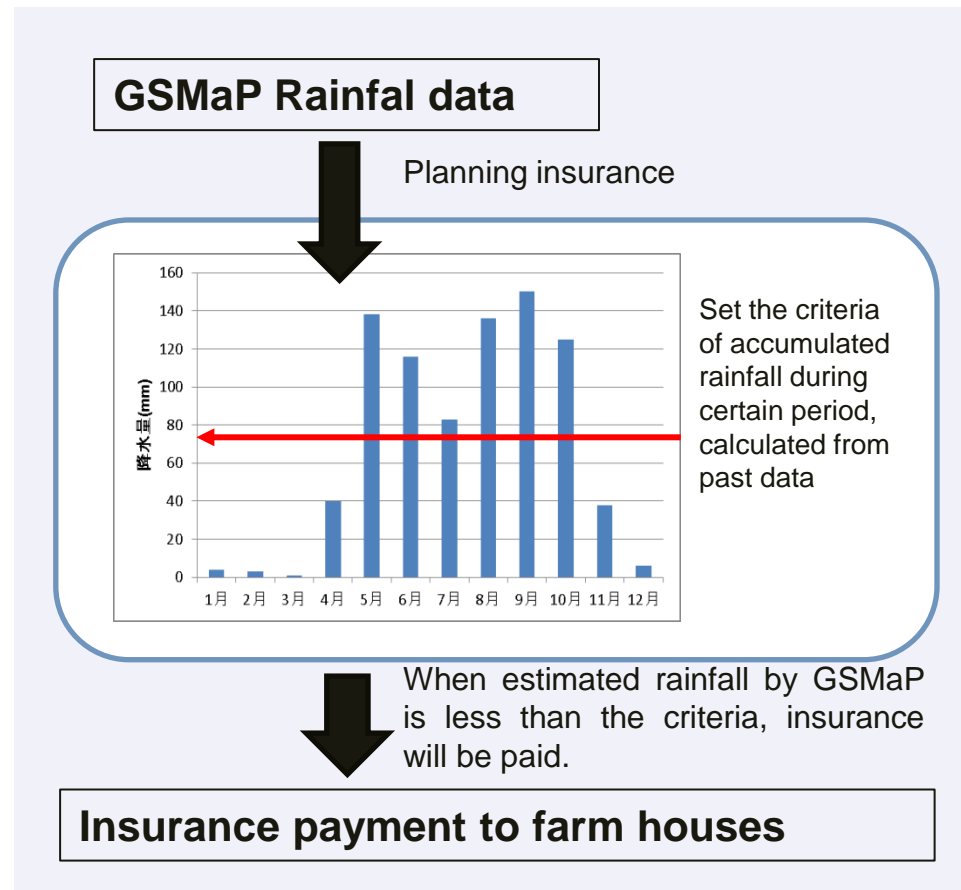
INPUT



GSMaP in Agricultural Insurance



- Japanese insurance company has developed Weather Index Insurance in Myanmar using GSMaP rainfall data, and plans to sell it in 2015
- In Myanmar, agriculture makes up 40% of GDP, but natural disasters such as droughts happens often recently.
- Overview of the insurance
 - Assured persons: farm houses in the assured regions
 - Assured crops: rice, sesame
 - Assured regions: Arid regions in the central Myanmar
 - Assured risks: drought (risk of less rainfall in rainy season)
- Plan to expand the insurance to other disaster risks (cyclone, heavy rainfall) in Myanmar, and to other countries in South-East Asia



A "Food Security Package" research using GSMaP by a fund of the MEXT

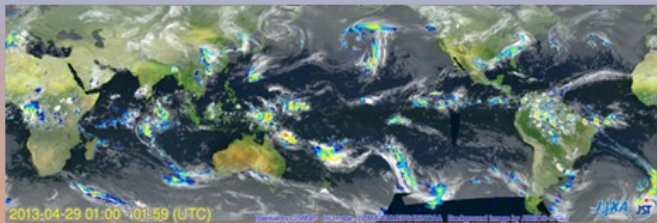


Food Security Package: Utilizing High Frequency Satellite Products with Integrated Land Process Models (SiBUC & SIMRIW) & Short-time Prediction with Cloud Resolving Model (CReSS)

By Higuchi (Chiba Univ.)

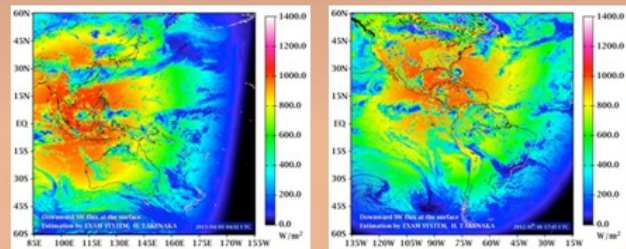
High Time Frequency Forcing Data by RS

Precipitation: GSMaP



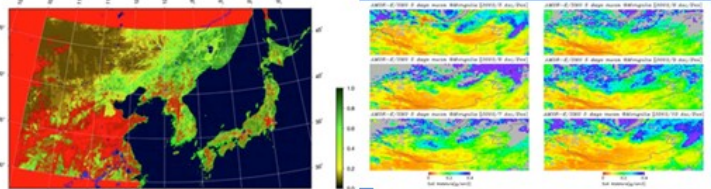
<http://sharaku.eorc.jaxa.jp/GSMaP/>

Solar Radiation: EXAM



<http://atmos.cr.chiba-u.ac.jp/takenaka/>

RS Products for Model Input and/or Validation



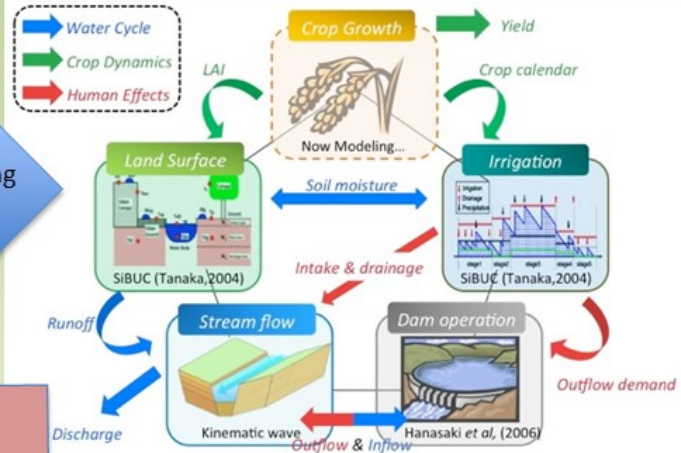
Biomass by Optical Sensor

Soil Moisture by AMSR2

"Real" Forcing to Model

Model Validation
Initial condition check

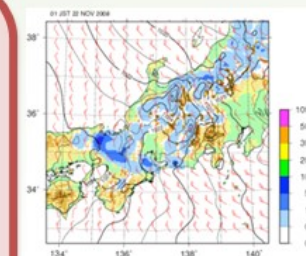
Integrated Land Process Modeling
Hydrology [SiBUC]+ Crop Growth [SIMRIW]



More realistic initial condition estimation

Short-term Prediction by CReSS+SiBUC (CReSiBUC) (1-5 days forecast)

- Integrated Research Demonstration: Satellite Observation & Numerical Modeling
- Test Short-term Alert system for crop yield
- Real-time system operation as a test of "infra-structure" for food security.



Summary



- Global Satellite Mapping of Precipitation (GSMaP)
 - Japanese product of the GPM mission
 - Processing and distributing global rainfall data in near real time basis (about 4-hour after observations) by merging multi-satellite data.
 - Hourly product in 0.1x0.1deg. lat/lon grid.
 - GPM-GSMaP data is now available from JAXA G-portal (<https://www.gportal.jaxa.jp>) as well as current GSMaP web site (<http://sharaku.eorc.jaxa.jp/GSMaP/>).
 - GSMaP_NOW is now available at http://sharaku.eorc.jaxa.jp/GSMaP_NOW/index_j.htm
- GSMaP application
 - About 1600 registered users as of 31 Aug. 2015
 - About 67% users are originated from foreign countries.
 - Flood Analysis with ICHARM
 - “Food Security Package” research under a fund of the MEXT.

