Introduction of Global Satellite Mapping of Precipitation (GSMaP)

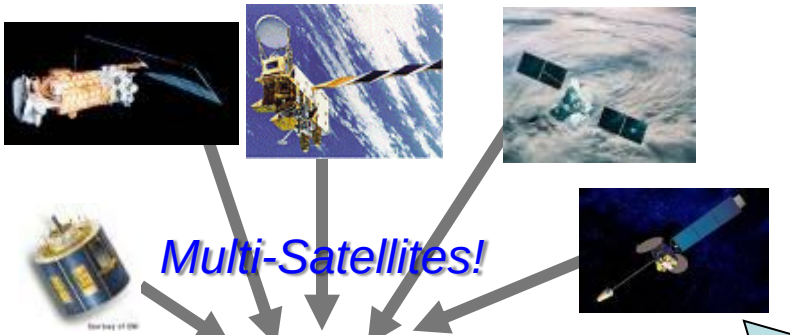
Satoshi Kida, Takuji Kubota, Misako Kachi, and Riko Oki (JAXA/EORC)

Outline

- Introduction of GSMaP products
  - GSMaP near real time system
- GSMaP algorithm
  - Remote sensing from space using electromagnetic waves
  - Principle of GSMaP algorithm
- Updates and future plans for GSMaP
  - Updates of GSMaP
  - Introduction of GCOM-W1/AMSR2 and GPM/DPR

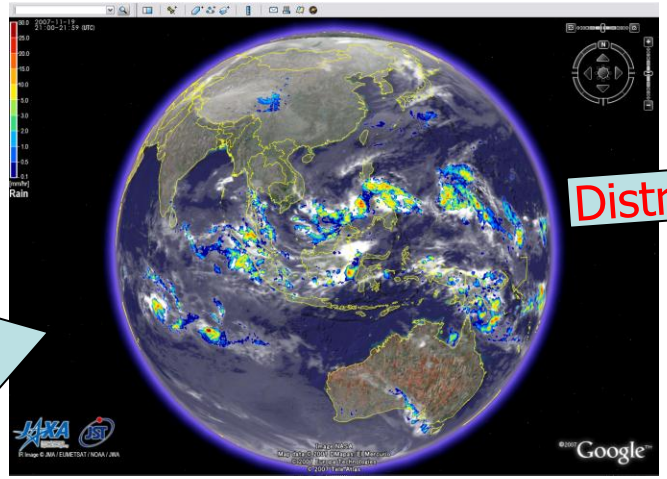
Global Satellite Mapping of Precipitation (GSMaP)

We have started to release hourly global rainfall data (GSMaP Product) in near real time (about four hours after observations). Grid resolution of the GSMaP is 0.1 degree lat/lon.



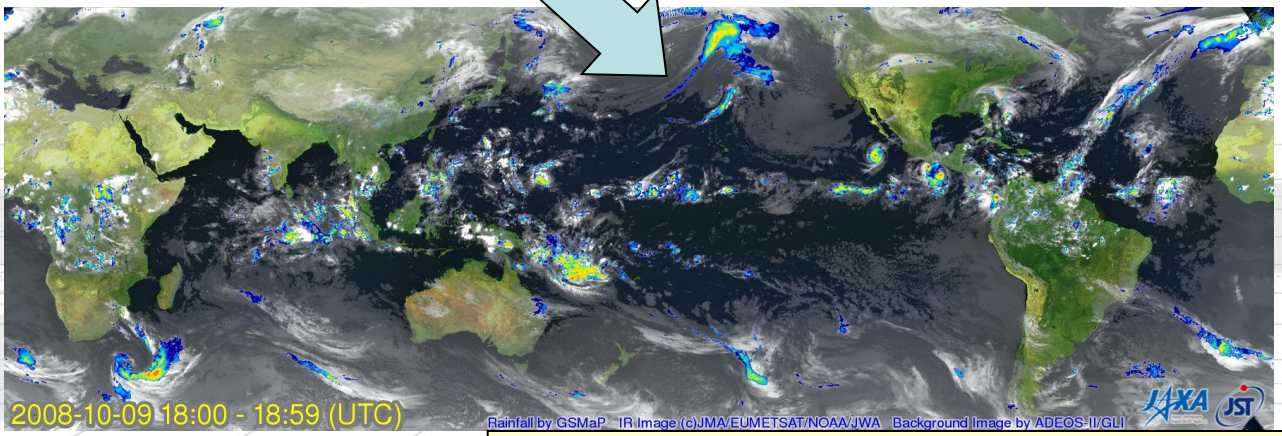
Multi-Satellites!

Produced Rainfall Map



Distribution

produced 4 hours after observation and updated every hour



Distribution

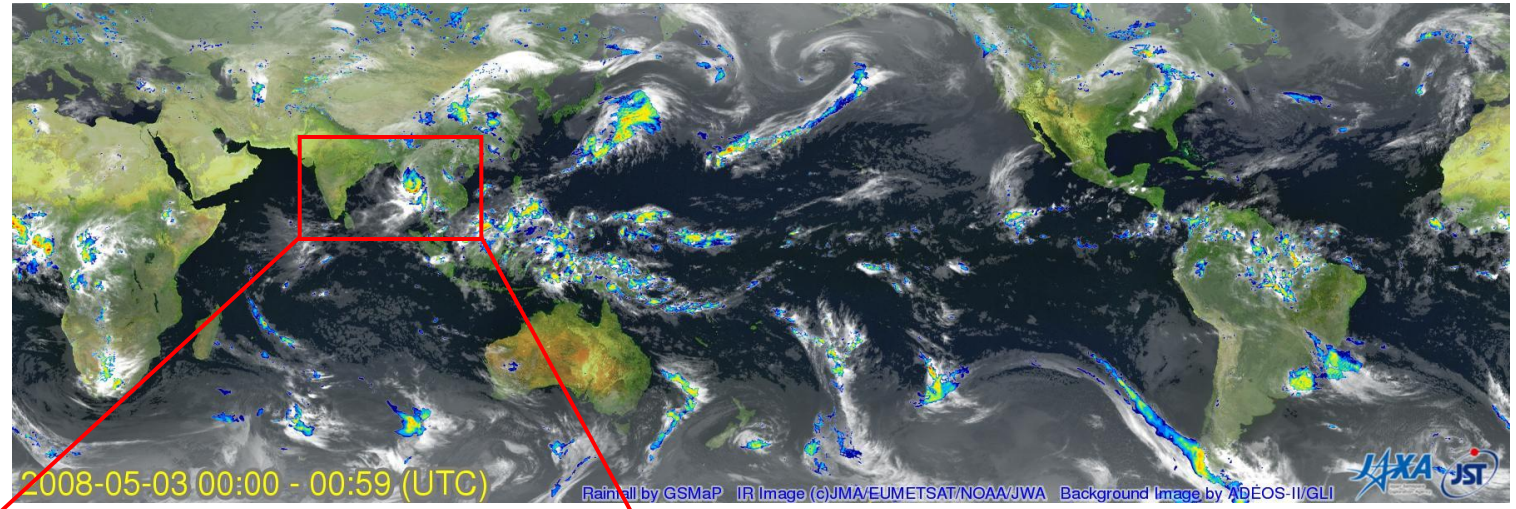
Internet access

- Images & Movies
- Google Earth files
- Data download

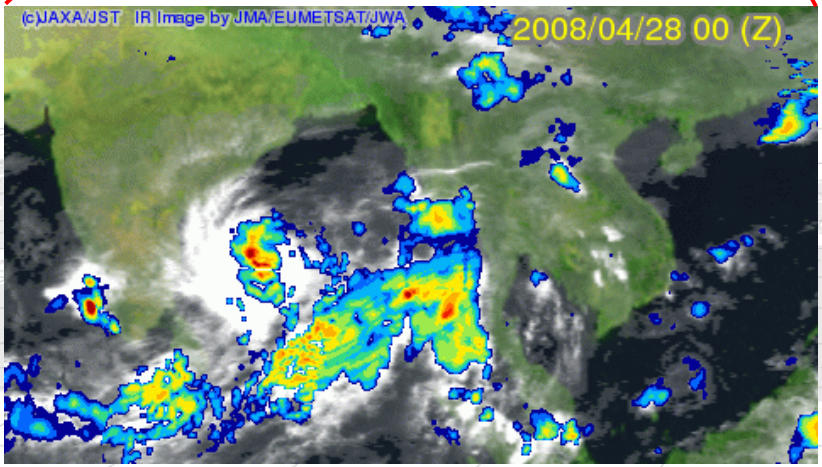
http://sharaku.eorc.jaxa.jp/GSMaP/

Rainfall observations by the GSMaP

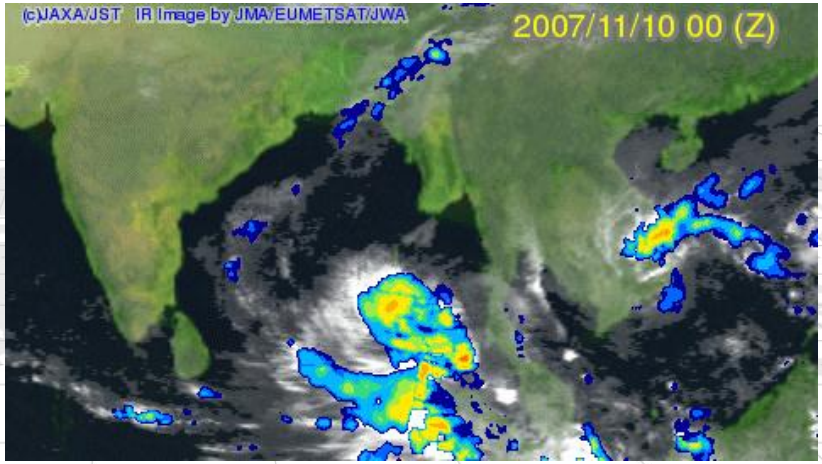
Global rainfall image with cloud images on 0UTC, 3rd May 2008



Movie from 28th April to 3rd May 2008 for cyclone “Nargis”



Movie from 11th to 16th November 2007 for cyclone “Sidr”

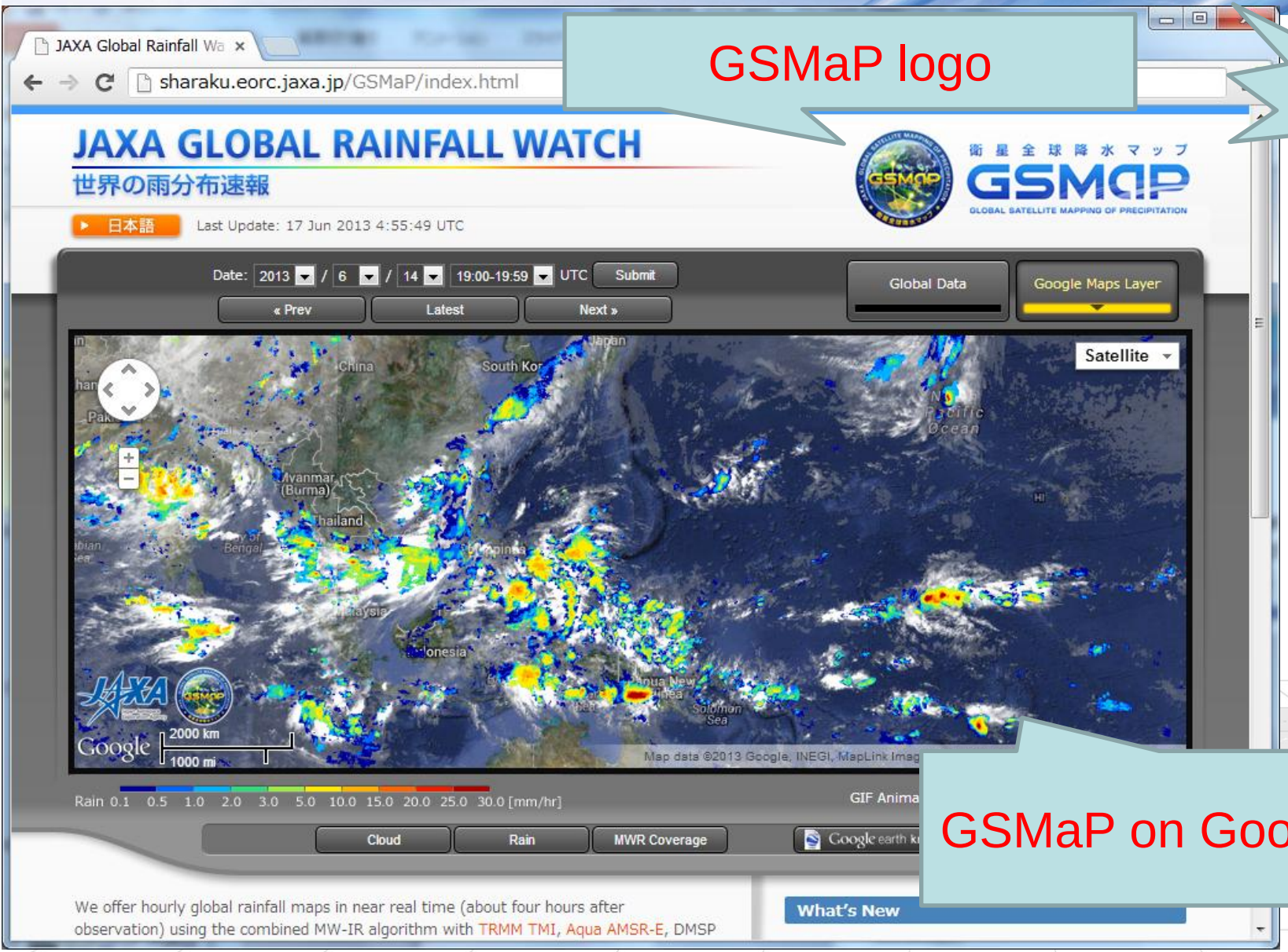


JAXA Global Rainfall Watch

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

The GSMaP data are freely available to research and education purpose.

Renewal of JAXA Global Rainfall Watch



GSMaP logo

Coming soon!!

GSMaP on Google Map

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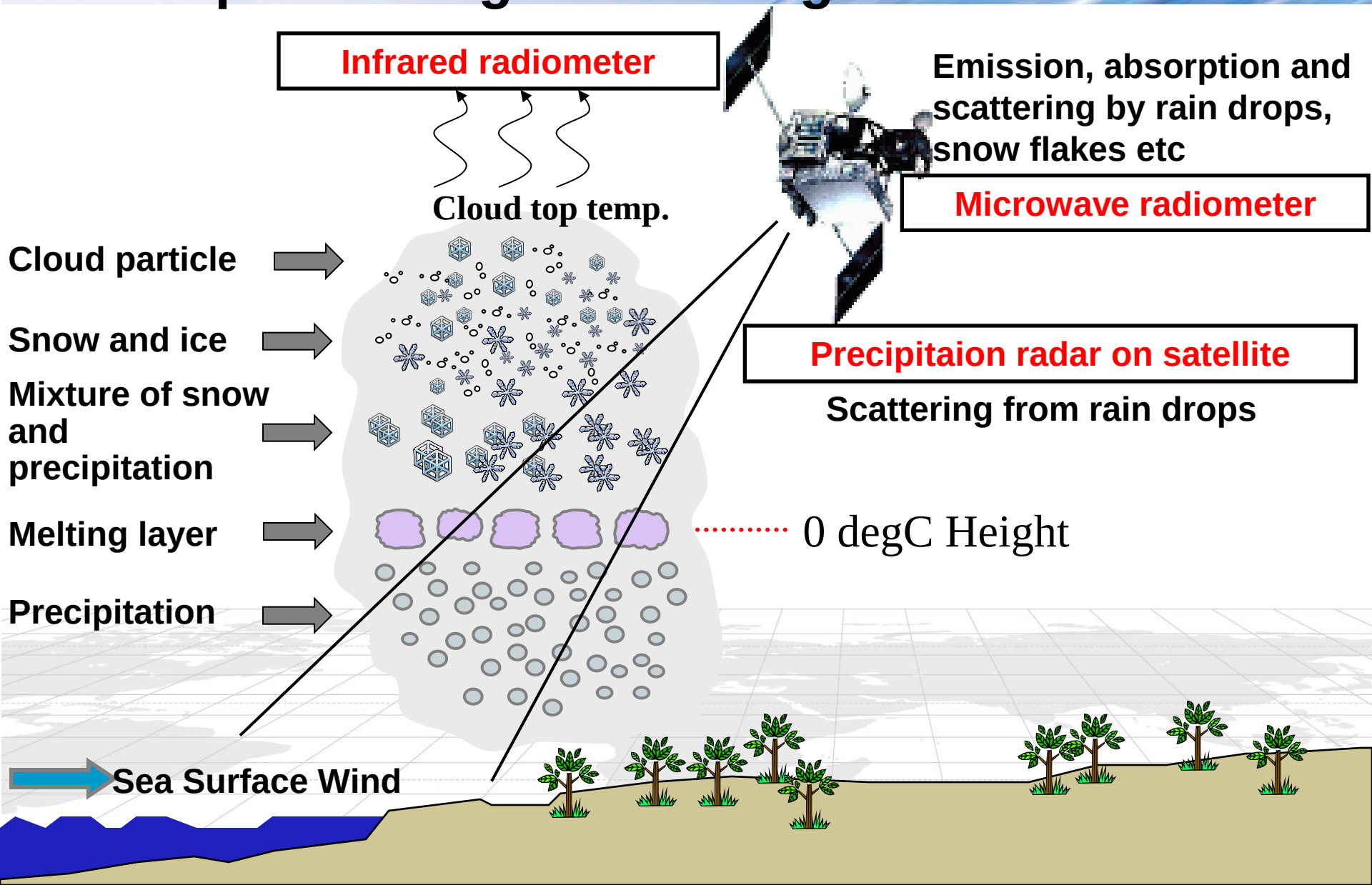
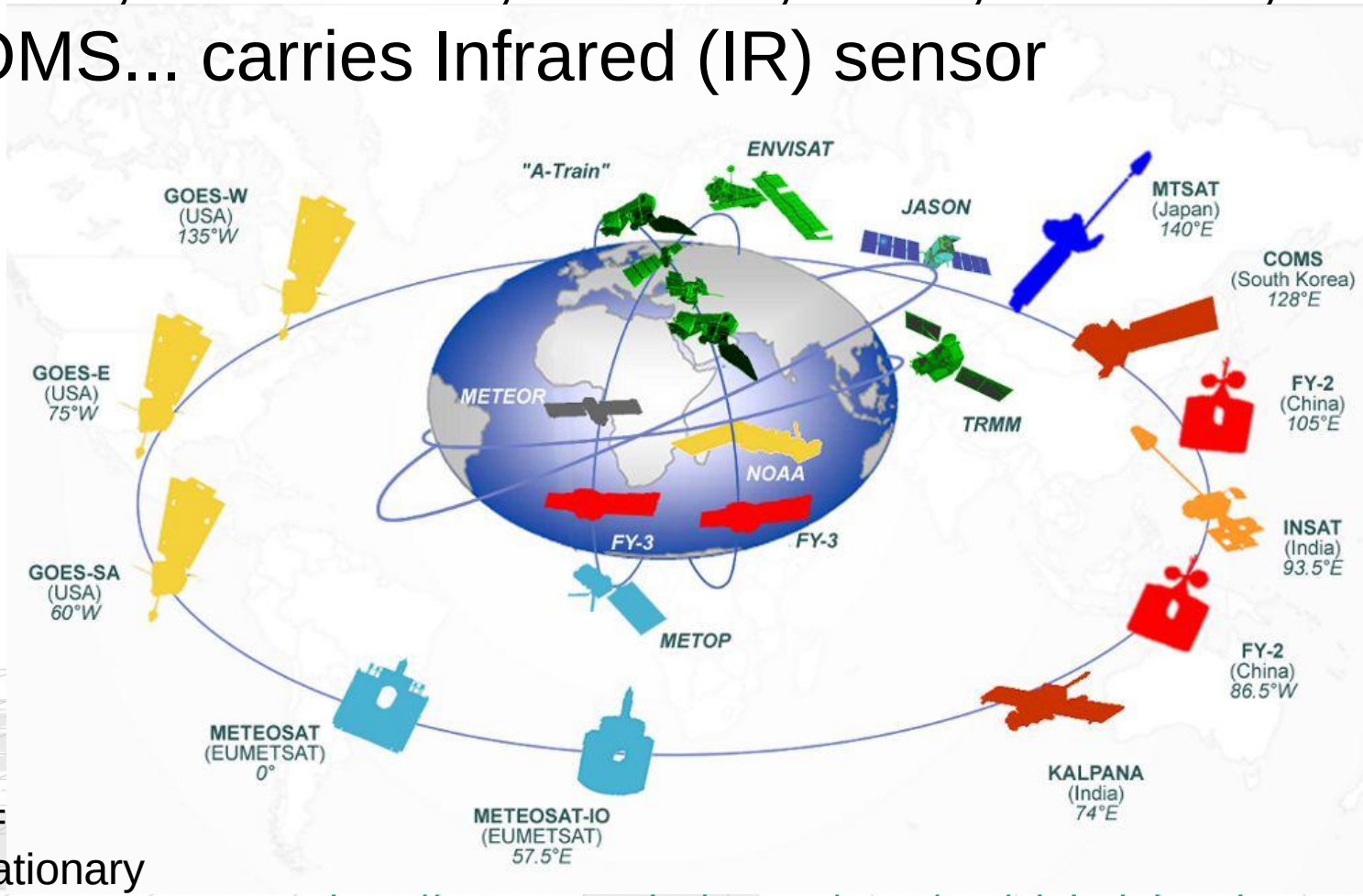
  - Updates of GSMaP
  - Introduction of GCOM-W1/AMSR2 and GPM/DPR

Remote Sensing of precipitation and clouds from space using electromagnetic waves



Operational geostationary satellites

- GOES, METOSAT, MTSAT, FY-2, INSTAT, COMS... carries Infrared (IR) sensor



GEO = Geostationary Earth Orbit

http://www.wmo.int/pages/prog/sat/globalplanning_en.php

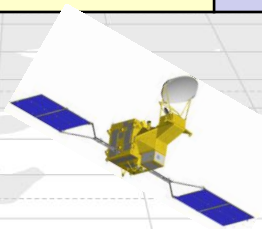
Microwave radiometers (conical scan)

Sensor	SSM/I	TMI	AMSR-E	SSMIS	Windsat	AMSR2	GMI
Satellite	DMSP series (~F15)	TRMM	Aqua	DMSP series (F16~)	Coriolis	GCOM W1	GPM
Provider	DoD, U.S.	NASA	JAXA	DoD, U.S.	NASA	JAXA	NASA
Frequency [GHz]	19.35 - 85.5	10.65 – 85.5	6.93 – 89.0	19.35 – 183.3	6.8 – 37.0	6.93 – 89.0	10.65 – 183.3
Swath width [km]	1400	700	1450	1700	1000	1450	890
Antenna size [m]	0.61	0.61	1.6	0.61	1.8	2.0	1.2

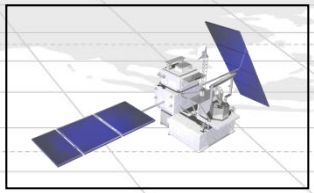
DMSP series

TRMM

Aqua



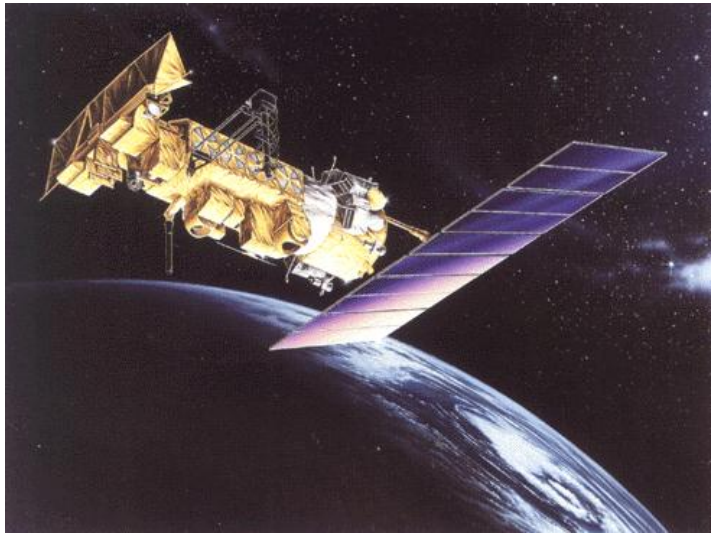
GCOM-W1



GPM Core

AMSU/MHS

- AMSU(Advanced Microwave Sounding Unit) is carried by NOAA KLM satellites (NOAA 15(-K), 1998-; NOAA 16(-L), 2000-; NOAA 17(-M), 2002-)
- MHS (Microwave Humidity Sounder) is similar to AMSU-B, and carried by NOAA 18, 19, Metop-A, Metop-B



Observation swath: 1650km
Footprint size of AMSU-B/MHS:
16km at nadir, but it changes according to observation directions.)

Channel	MSU	AMSU-A	AMSU-B
1	50.30	23.8	89.0
2	53.74	31.4	150.0
3	54.96	50.3	183.3±1
4	57.95	52.8	183.3±3
5		53.6	183.3±7
6		54.4	
7		54.9	
8		55.5	
9		57.2	
10		57.29±.217	
11		57.29±.322±.048	
12		57.29±.322±.022	
13		57.29±.322±.010	
14		57.29±.322±.0045	
15		89.0	

(GHz)

http://amsu.cira.colostate.edu/

http://www2.ncdc.noaa.gov/docs/klm/html/c3/sec3-4.htm

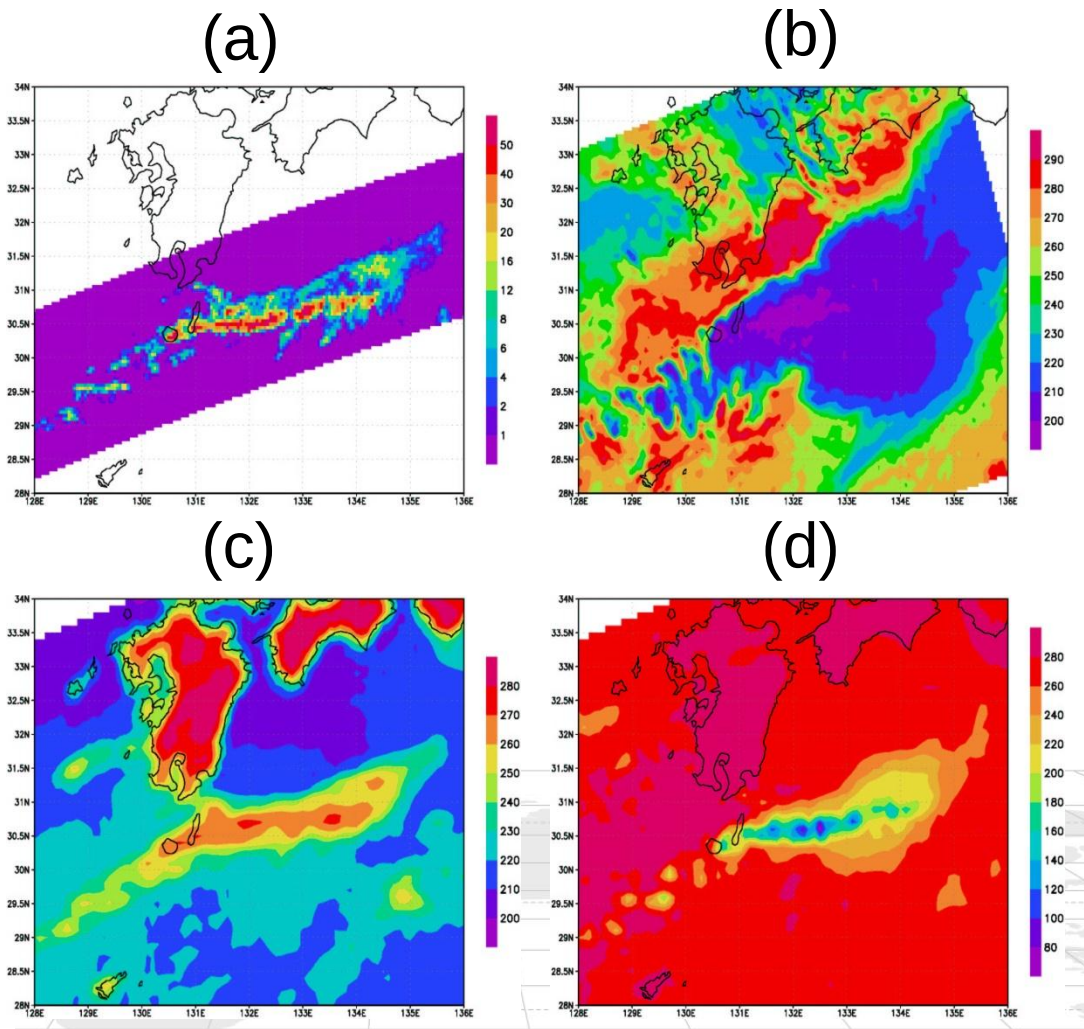
Passive microwave and other sensors

(a) Precipitation radar
Back scattering from rain drops
High accuracy
Narrow swath width

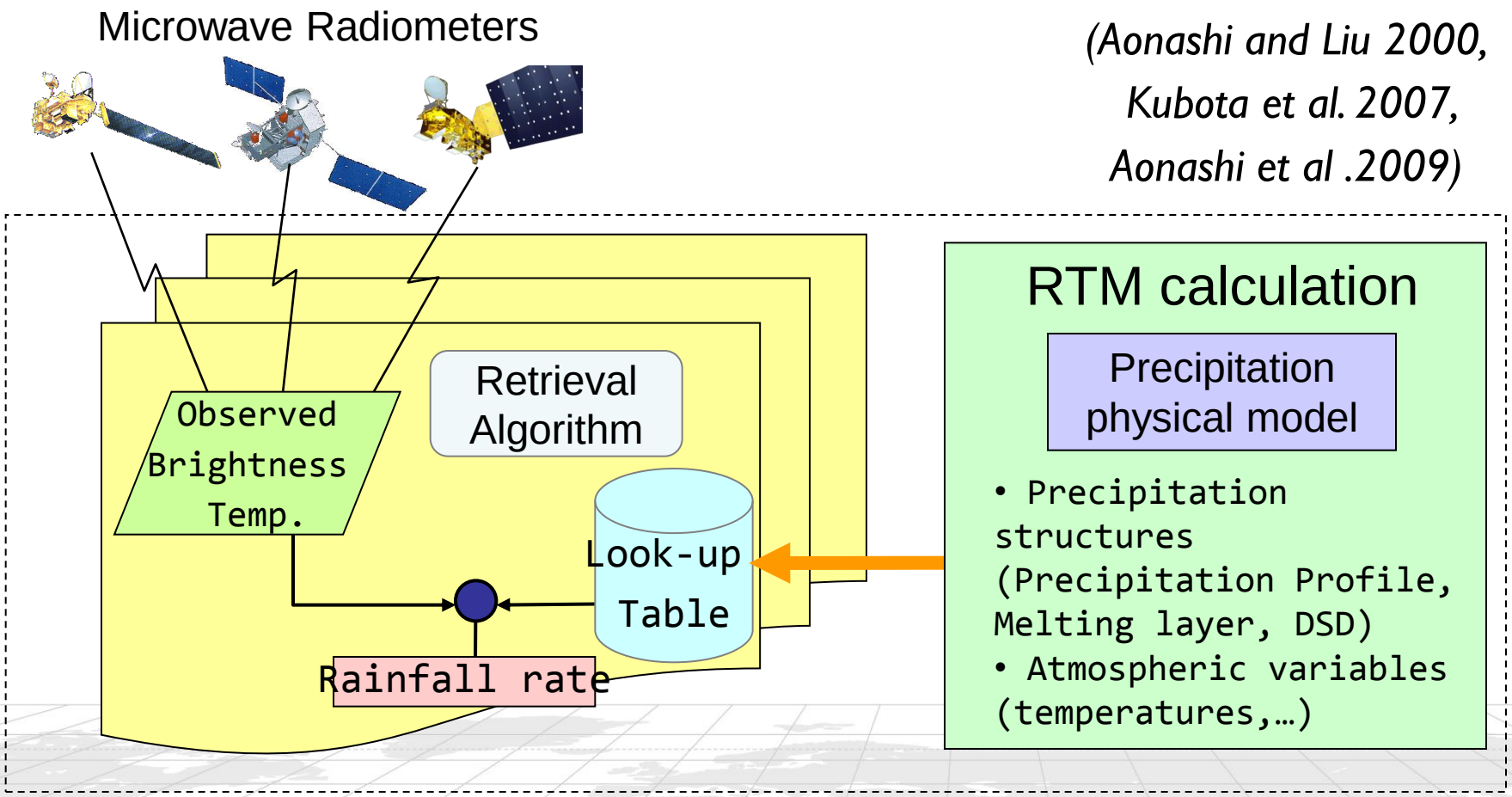
(b) Infrared radiometer:
Cloud top information
Not related to surface precipitation rates

(c) Passive microwave radiometer(19GHz):
(d) Passive microwave radiometer(85GHz):

Directly measures the emission from precipitation at 19GHz, and scatter at 85GHz.



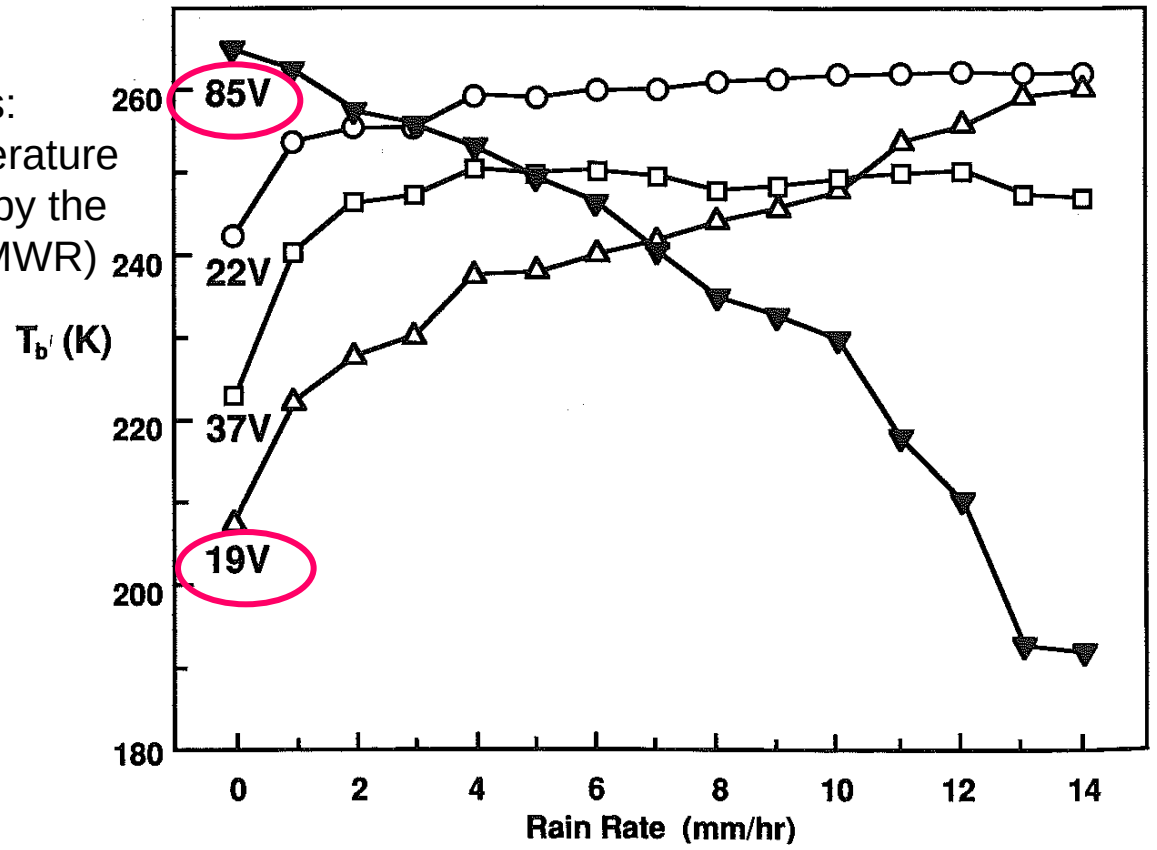
Basic Idea of GSMaP_MWR algorithm



The relationship between rain rate and brightness temperature is tabulated by assumption of precipitation physical model and calculation of the radiative transfer model (RTM).

T_b vs Rain Relationship

Vertical axis: Brightness temperature (Tb) (observed by the satellite-borne MWR)

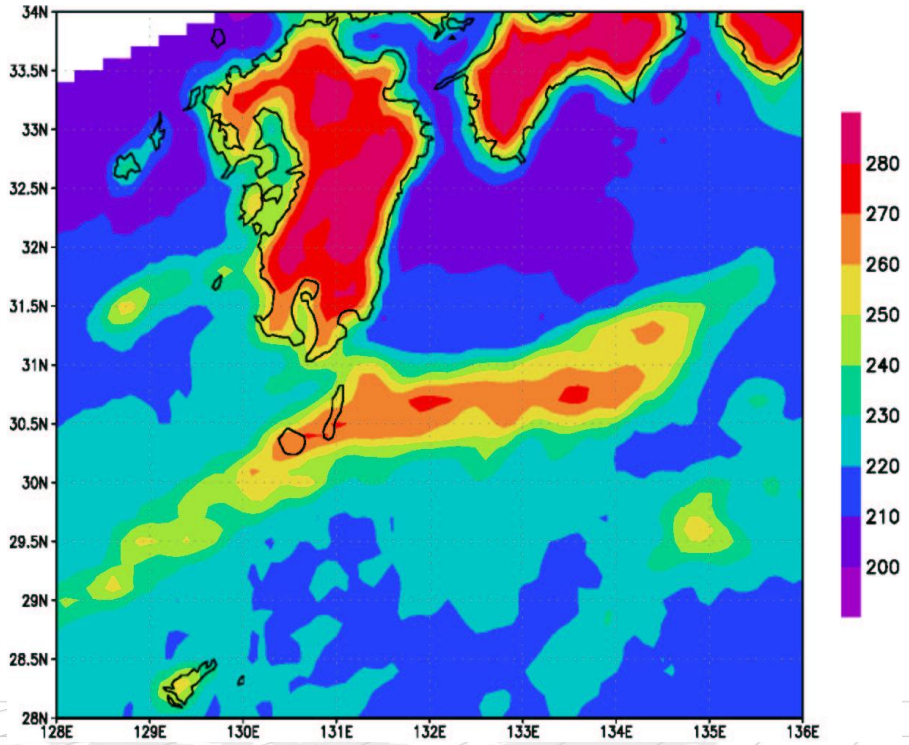


(Grody 1993)

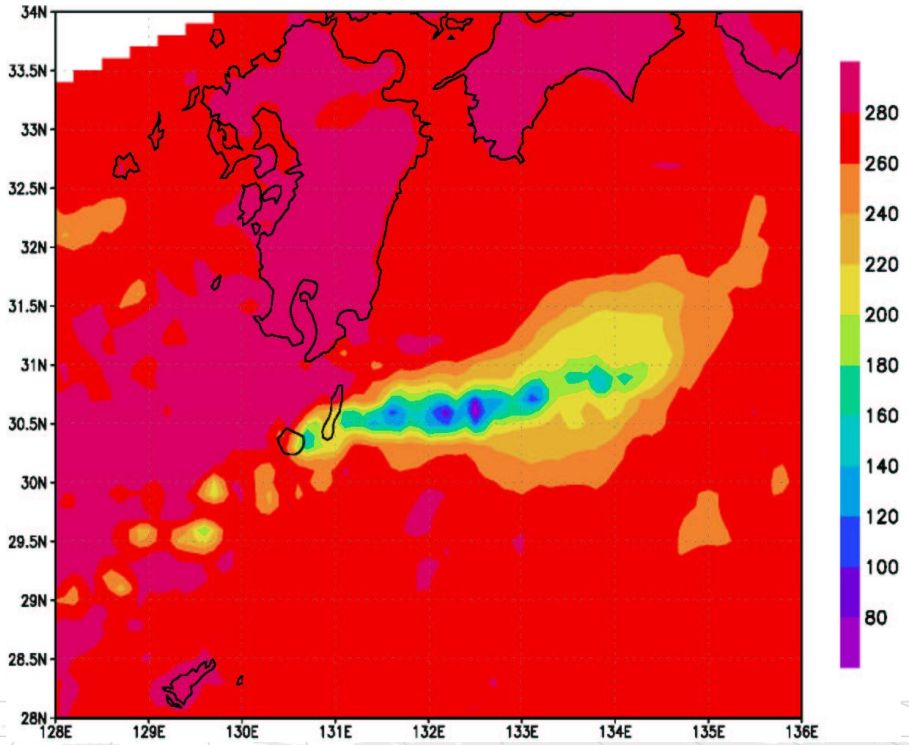
Vertically polarized brightness temperatures (T_bs) at 19, 22, 37, and 85 GHz corresponding to rain rates

MWR observation example

(c) Microwave Radiometer (19GHz)



(d) Microwave Radiometer (85GHz)

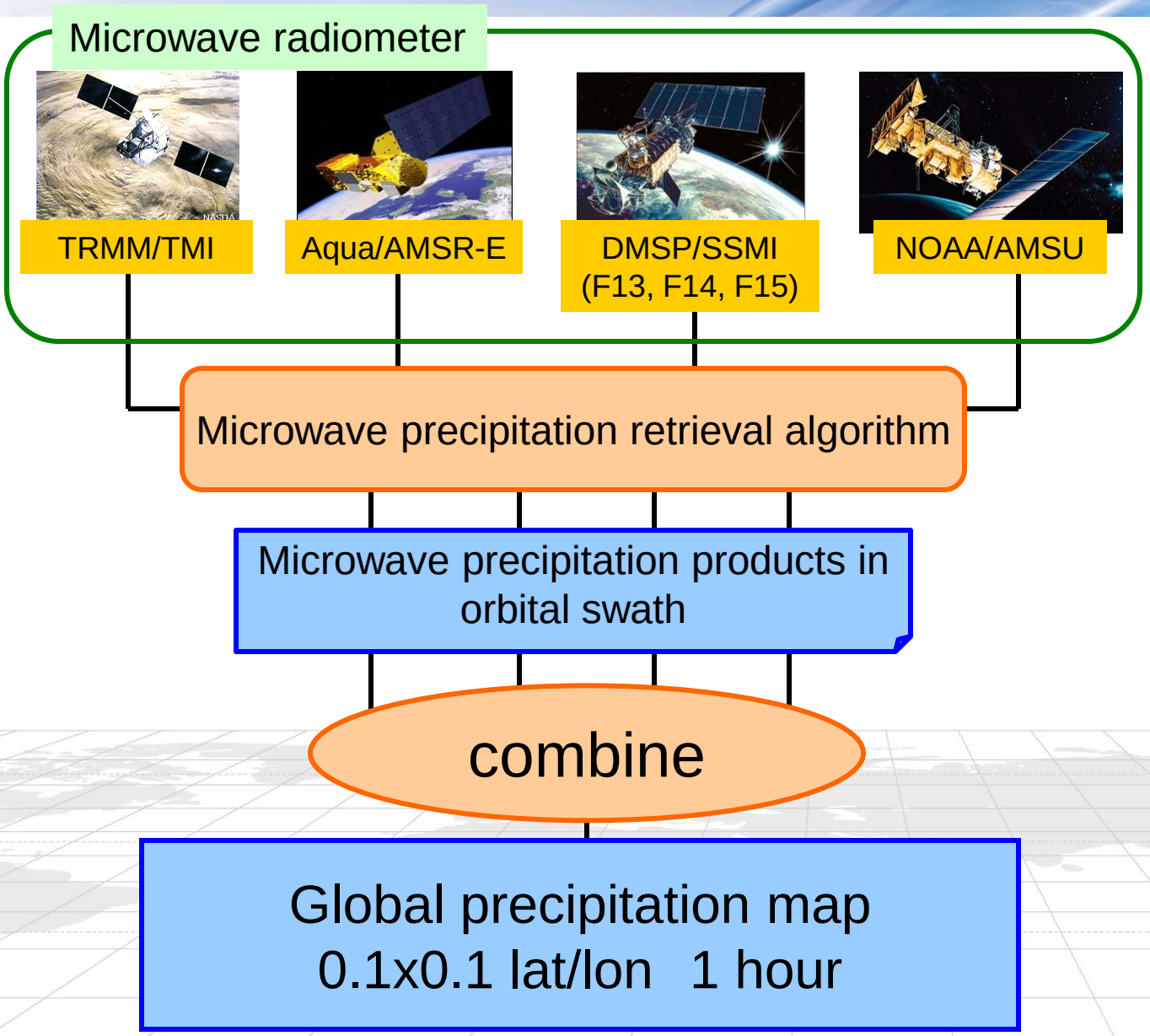


- Emission from rain drops over sea
- High and variable emissivity of the land surface

Scatter by frozen precipitation over land /sea

Wider observation swath of the TMI than that of the PR
(TMI swath is 760km)

Flowchart of global precipitation map



Flowchart of global precipitation map

Microwave radiometers

Retrieval algorithm

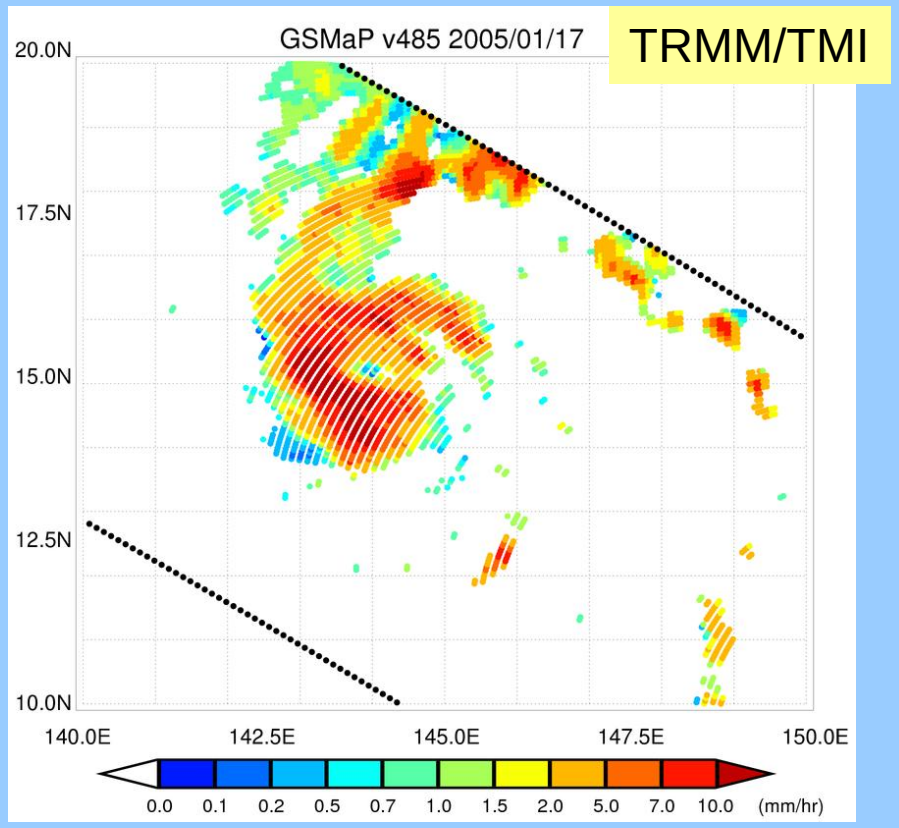
Microwave precipitation products in orbital swath

combine

Global precipitation map
0.1 deg., 1 hourly

Orbital rain retrieval product

TB in a field-of-view (FOV) of each microwave radiometer are converted to rain rate.



Flowchart of global precipitation map

Microwave radiometers

Retrieval algorithm

Microwave precipitation products in orbital swath

combine

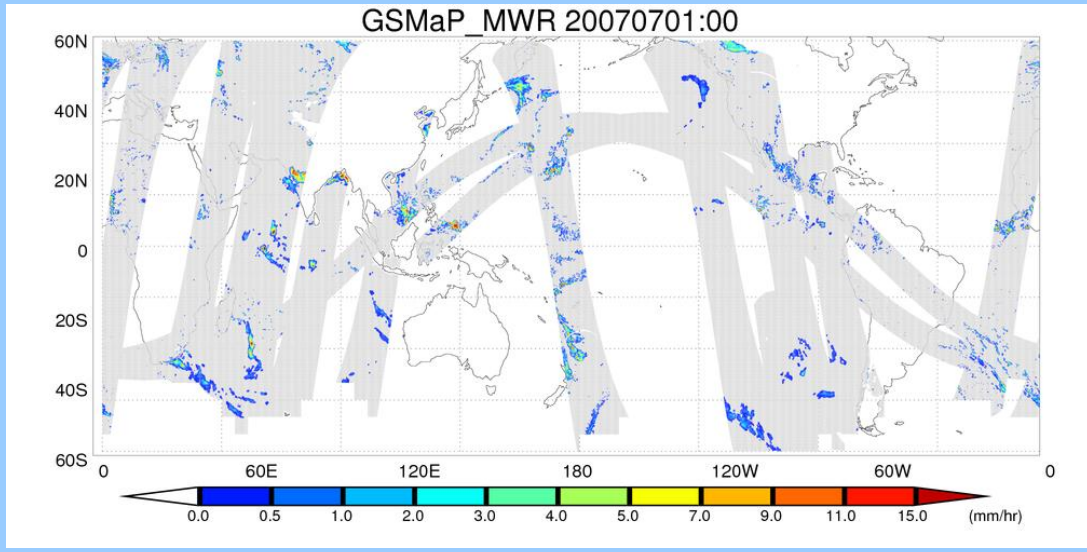
Global precipitation map
0.1 deg., 1 hourly

Global precipitation map

0.1 deg., 1 hourly

○Data

- TRMM / TMI
- Aqua / AMSR-E
- DMSP / SSM/I F13, F14, F15
- NOAA / AMSU-15, 16, 17



Strength and Weaknesses of Each Sensor

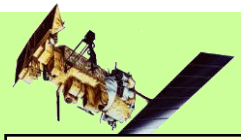
- Each sensor has strength and weaknesses.
  - Microwave passive sensor has
    - Very good correlation to precipitation
    - Emission not useful over land
    - No operational estimates over frozen surfaces
    - The major draw back is temporal sampling due to low earth orbit satellite (LEO)
  - Infrared (IR) sensor has
    - Excellent sampling from Geostationary Earth Orbit (GEO) satellites
    - Weak instantaneous relationship to precipitation
    - Weak mean relationship outside 40 degree
  - → Blended Microwave-IR approach

Production of GSMaP by Multi-satellite Data

TRMM
TMI

Aqua
AMSR-E

DMSP
SSM/I, SSMIS



NOAA
AMSU-A/B
&MHS

Geostationary
Satellites/IR

GSMaP
Microwave Radiometer (MWR)
Algorithm

Products of Each Microwave
Radiometer Data

GSMaP_MVK algorithm
(IR-MWR Merged
algorithm)

GSMaP Product

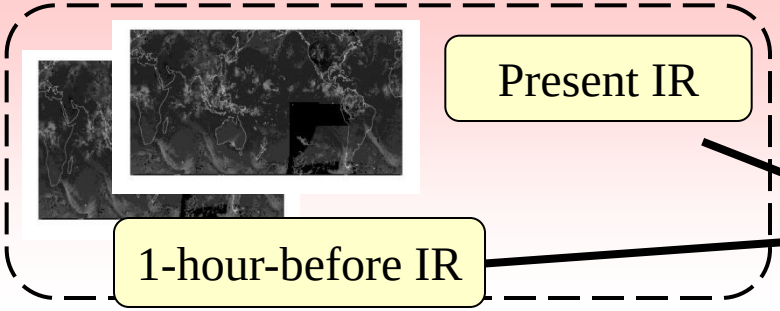
0.1-deg. lat/lon grid, hourly

Currently, TRMM/PR provides "reference standard" of the GSMaP.

Flowchart of Blended MWR-IR algorithm (GSMaP_MVK algorithm)

Ushio et al. (2009)

GEO IR data



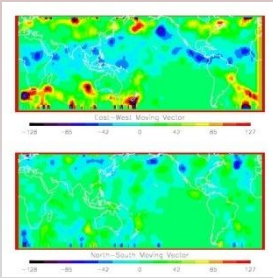
Present IR

1-hour-before IR

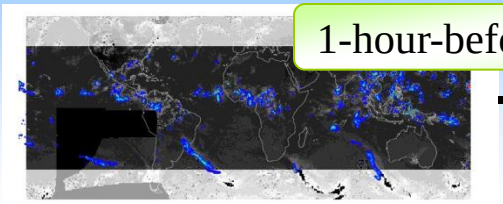
Cloud motion vectors

Zonal

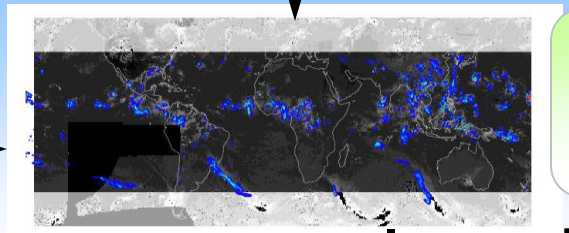
Meridional



Past GSMaP data



1-hour-before GSMaP

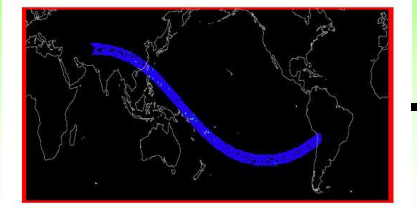


GSMaP interpolated by the motion vectors

Kalman filter

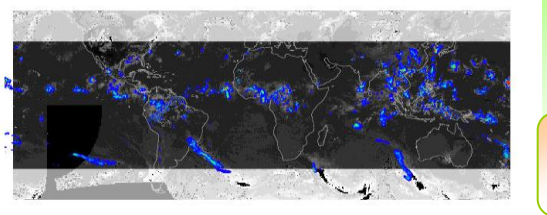
Present MWR data

MWR data observed during present 1 hour



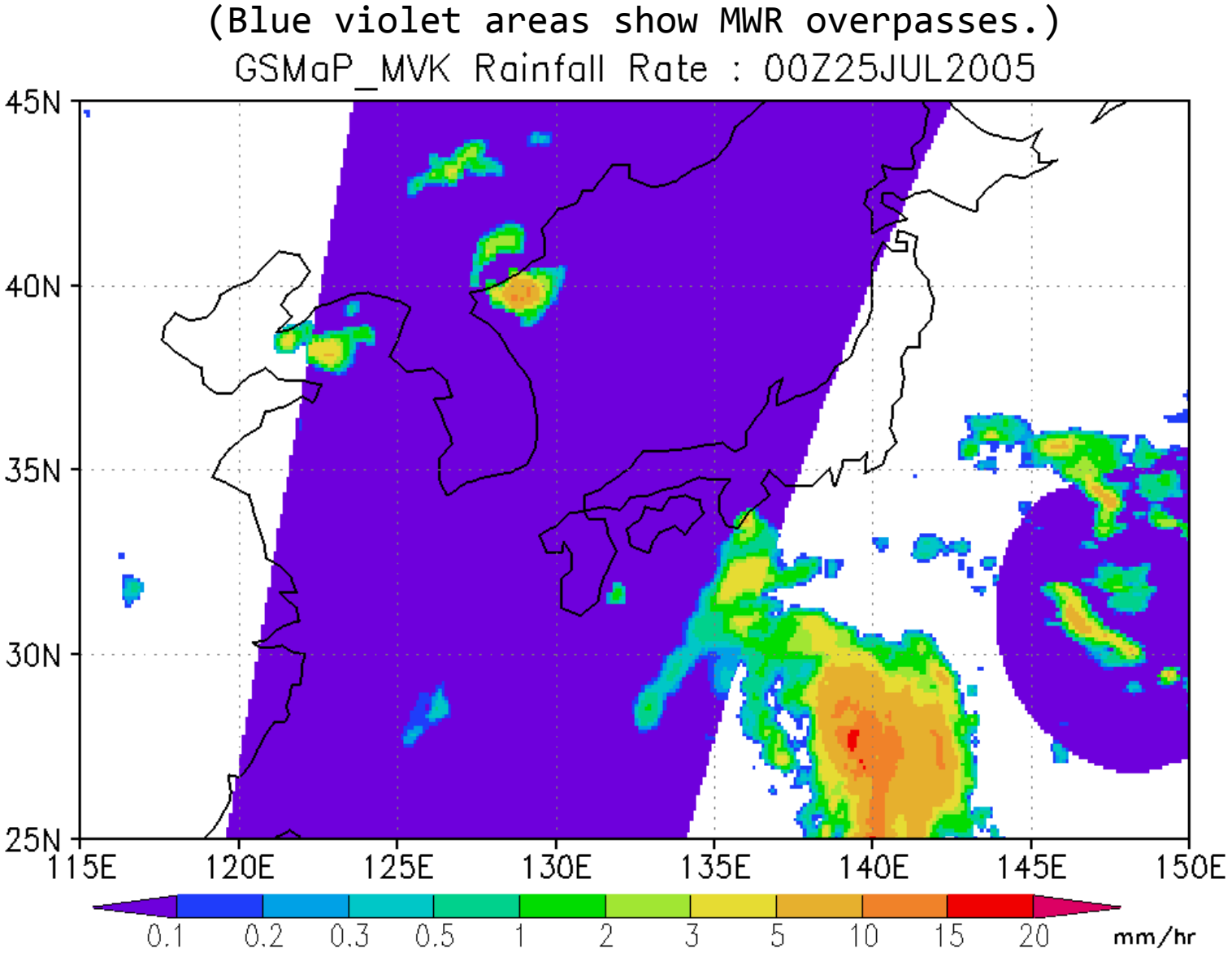
(MWR overpasses)

(Outsides MWR overpasses)



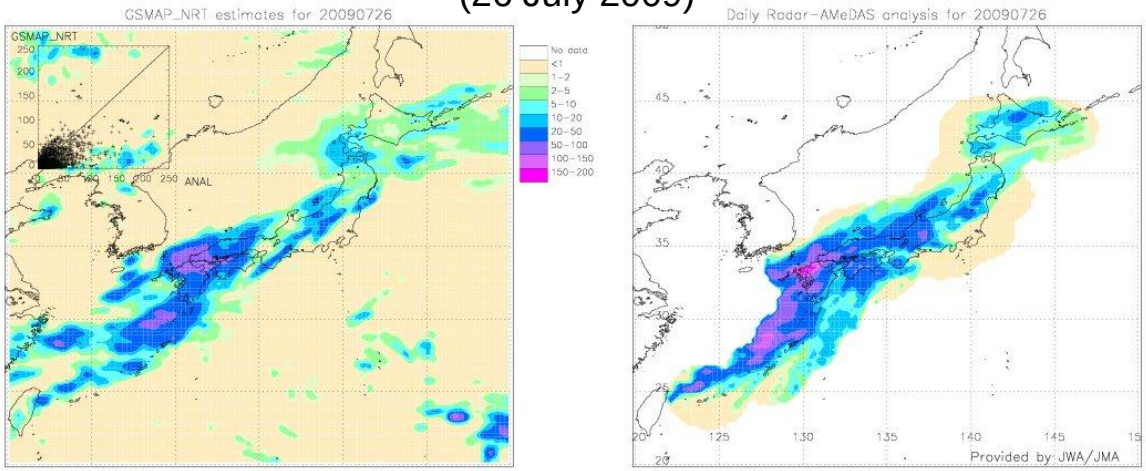
Present GSMaP

Typhoon 200507/BANYAN (hourly)



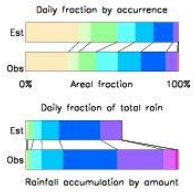
Validation using JMA Radar-AMeDAS analysis

GSMaP_NRT (26 July 2009) Radar-AMeDAS



http://www-ipwg.kugi.kyoto-u.ac.jp/IPWG/dailyval.html

daily averages
0.25 x 0.25 deg. resolution



Observed \ GSMAP_NRT	<1	≥1
<1	642	214
≥1	423	1783

Verification statistics for 20090726 n=3062 Verif. grid=0.25° Units=mm/day

	Analysed	GSMAP_NRT
# gridpoints raining	2206	1997
Average rain	15.2	9.5
Conditional rain	21.1	14.6
Rain volume (mm*km²x10⁶)	29.4	18.4
Maximum rain	220.0	93.8

Mean abs error = 10.1
RMS error = 18.2
Correlation coeff = 0.648
Frequency bias = 0.905
Probability of detection = 0.808
False alarm ratio = 0.107
Hanssen & Kuipers score = 0.558
Equitable threat score= 0.351

(White: missing values)

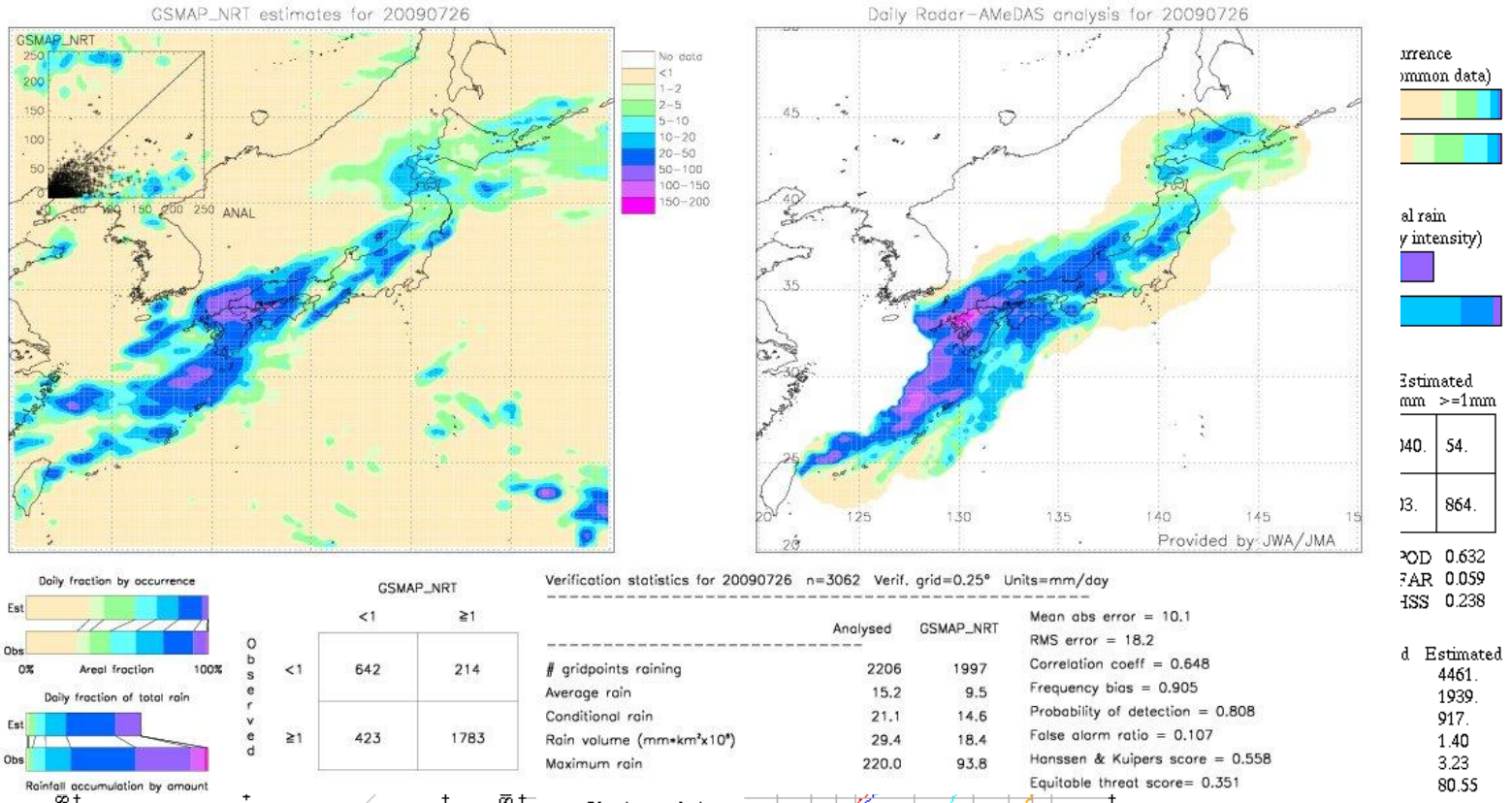
- Comparisons with reference to the gauge-calibrated ground radar dataset (JMA Radar-AMeDAS precipitation analysis)
- Developed and operated by Prof. Shige (Kyoto Univ.)'s group, which is now supported by the 6th JAXA PMM Science Research Announcement.

Collaboration in IPWG

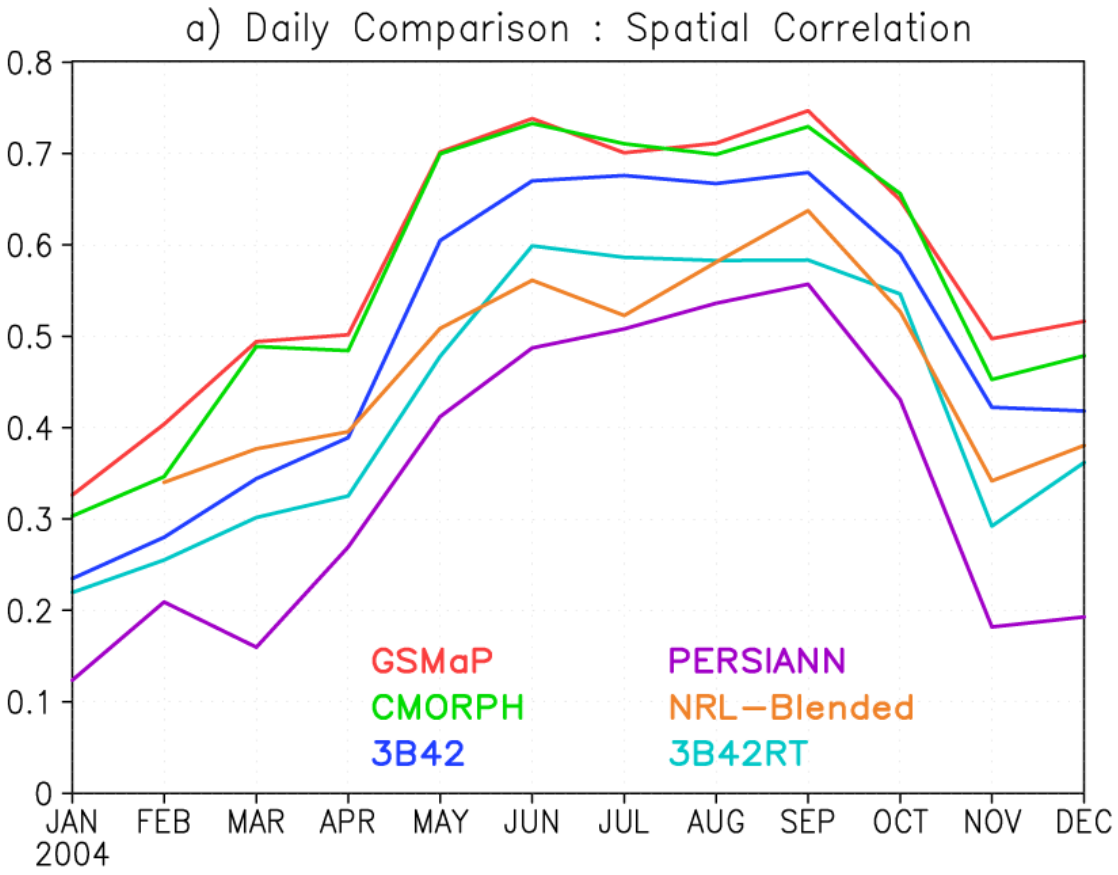
http://cawcr.gov.au/projects/SatRainVal/validation-intercomparison.html

The GSMaP joins the International Precipitation Working Group (IPWG) validation activities.

• Our GSMaP products are validated in U.S.(J. Janowiak), Australia (E. Ebert), South America (D. Vila), Europe (C. Kidd) and Japan (S. Shige) every day.



Validation results around Japan during 2004



Monthly averaged time series of correlation coefficients with daily estimates around Japan during 2004.

Horizontal resolution:
0.25x 0.25 latitude/longitude.

Reference: JMA Radar-AMeDAS precipitation analysis

6 global rainfall map products:

GSMaP

TMPA 3B42RT and 3B42 (Huffman et al. 2007)

CMORPH (Joyce et al. 2004)

PERSIANN(Sorooshian et al. 2000, Hsu et al.1997)

NRL-Blended (Turk and Miller 2005, Turk and Mehta 2007)

Better during the warm season,
related to false rainfall signals over surface snow,
consistent with validation results in other regions (e.g., Ebert et al. 2007)

Kubota et al. (2009, JMSJ)

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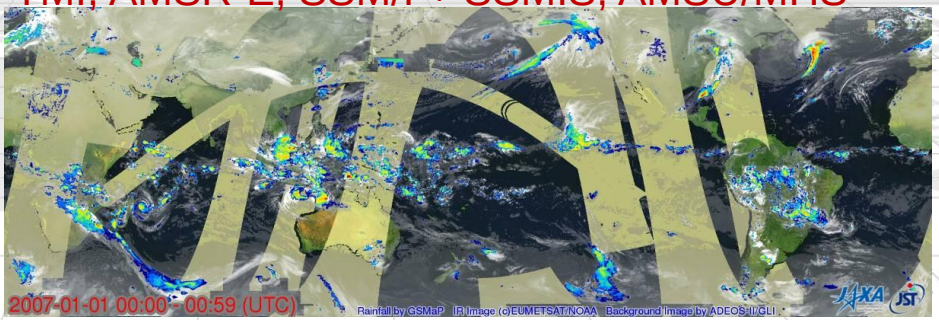
Updates of Near Real Time GSMaP system

http://sharaku.eorc.jaxa.jp/GSMaP/index.htm

- Improvements in sampling of observation for rainfall
  - DMSP SSMIS data have been merged into the system since 2010, and passive microwave sounder data from NOAA-19 and MetOp-A have been merged since 2011
  - Now, the GSMaP_NRT system is operated with 7 PMW data and GEO IR data
- Re-processing (re-collection and more elaborated algorithms)
  - We completed the re-processing with the period during **Mar. 2000- Nov. 2010** and the data are open to registered users.
- Released text version of re-analysis data in GIS format (Oct. 2012) due to many requests from flood community.
  - Now daily product only on the web. Hourly data will be available soon.
- Test version of GSMaP gauge-calibrated GPM product was released for limited users for evaluation. (Nov. 2012)
- Web site renewal (Jun. 2013), New GSMaP logo
- Introduction of GCOM-W1/AMSR2 (in preparation).

TMI, AMSR-E, SSM/I

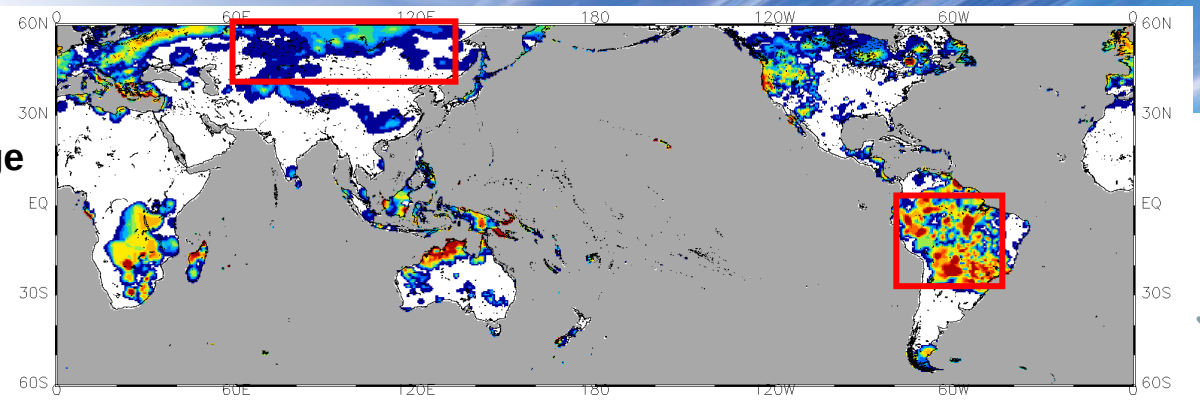
TMI, AMSR-E, SSM/I + SSMIS, AMSU/MHS



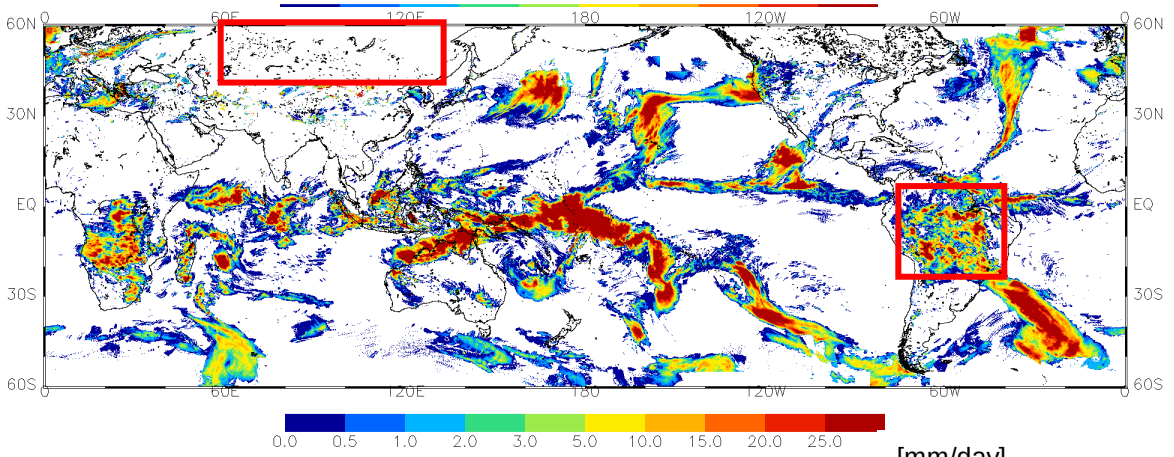
GSMaP_Gauge: merged GSMaP_MVK with NOAA CPC Gauge data

2004/01/01

NOAA CPC Gauge
0.5x0.5 deg.lat/lon
Daily

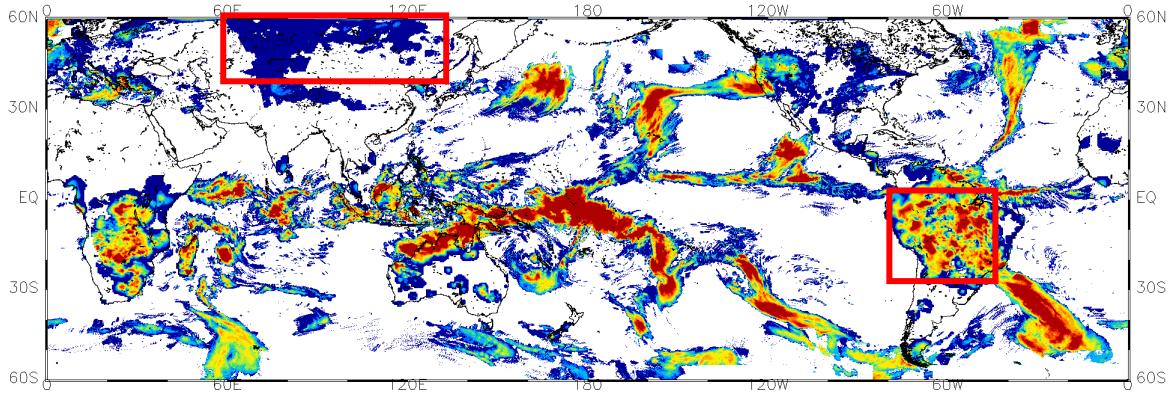


GSMaP_MVK
0.1x0.1 deg.lat/lon
Hourly
(displayed in daily average)



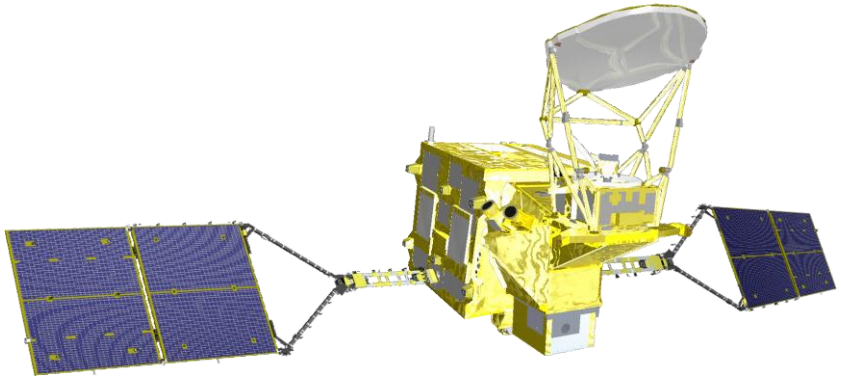
Coming soon!!

GSMaP_Gauge
0.1x0.1 deg.lat/lon
Hourly
(displayed in daily average)



GCOM-W1 and AMSR2

GCOM-W1 was launched on May 17, 2012 (JST) from Tanegashima Space Center.



GCOM-W1 (Water)

Instrument	Advanced Microwave Scanning Radiometer-2
Orbit	Sun Synchronous orbit Altitude : 699.6km (on Equator) Inclination: 98.2 degrees Local sun time: 13:30+/-15 min
Size	5.1m (X) * 17.5m (Y) * 3.4m (Z) (on-orbit)
Mass	1991kg
Power gen.	More than 3880W (EOL)
Launch	18 May 2012 by H-IIA Rocket
Design Life	5-years

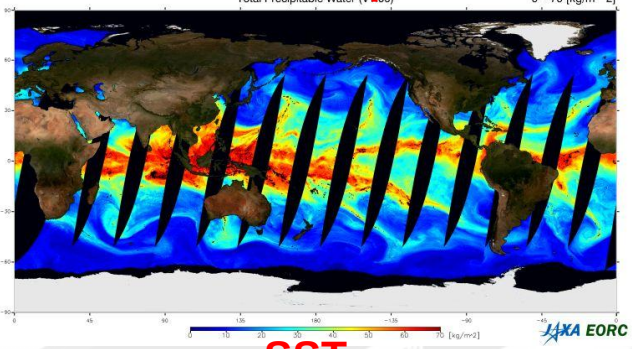
AMSR2 Channel Set				
Center Freq. [GHz]	Band width [MHz]	Pol.	Beam width [deg] (Ground res. [km])	Sampling interval [km]
6.925/ 7.3	350	V and H	1.8 (35 x 62)	10
10.65	100		1.2 (24 x 42)	
18.7	200		0.65 (14 x 22)	
23.8	400		0.75 (15 x 26)	
36.5	1000		0.35 (7 x 12)	
89.0	3000		0.15 (3 x 5)	5

Status of AMSR2 and GCOM-W1

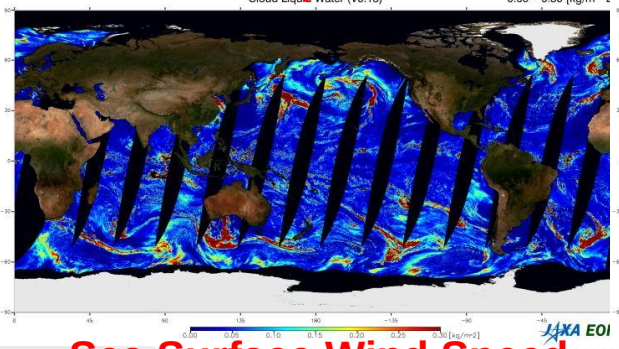
- **2012.5.18** GCOM-W1 (SHIZUKU) was launched
- **2012.6.29** Join A-Train orbit
- **2012.7.03** Start AMSR2 observation from A-Train orbit
- **2012.7.04** Release of AMSR2 observation images
- **2012.8.10** Initial functional verification completed
- **2012.8.31** Preliminary L1 delivery to PI and related agencies
- **2012.10.19** Preliminary L2 delivery to PI and related agencies
- **2013.1.24** L1 (and L3TB) public release from **https://gcom-w1.jaxa.jp/**
  L1 product information available at **http://suzaku.eorc.jaxa.jp/GCOM_W/**
- **2013.5.17** L2 (and L3GEO) public release

AMSR2 Standard Products

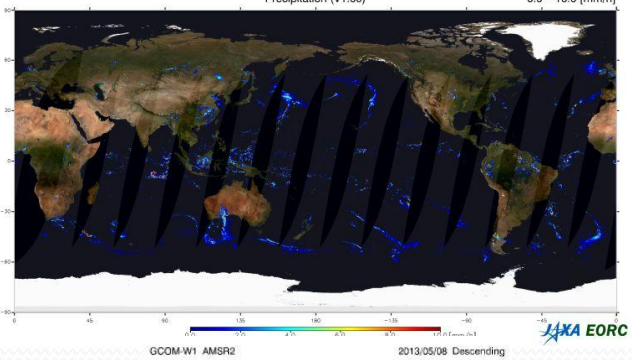
Water Vapor



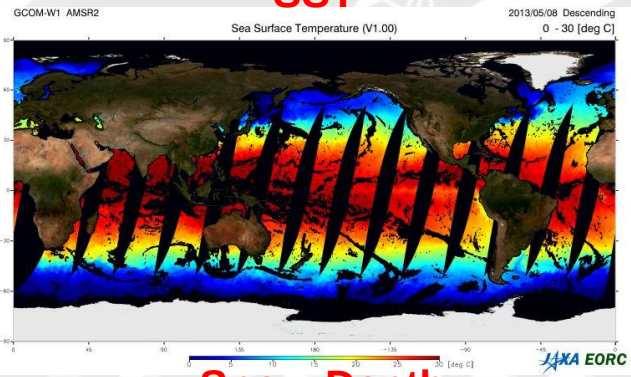
Cloud Liquid Water



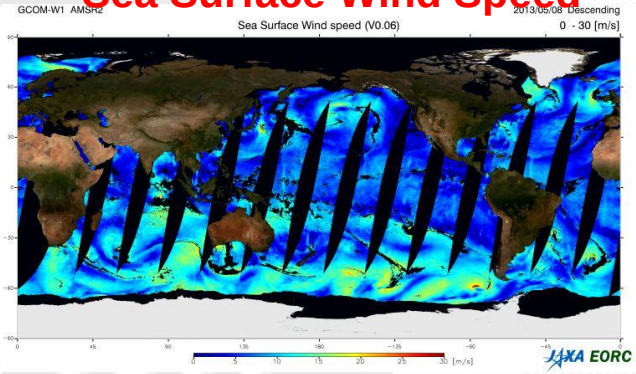
Precipitation

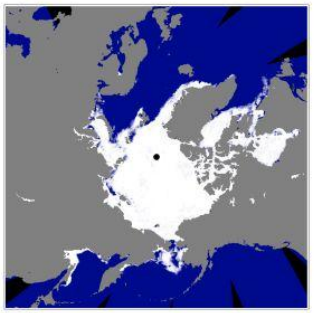


SST

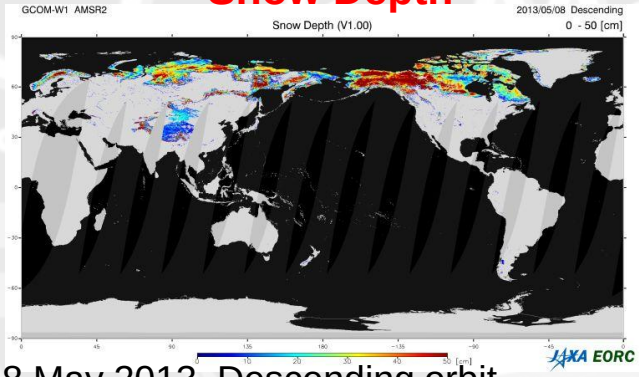


Sea Surface Wind Speed

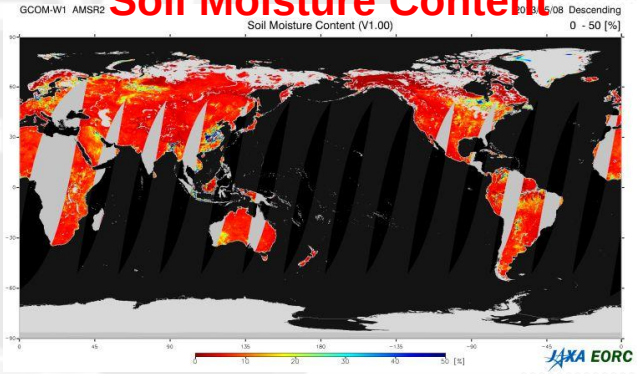




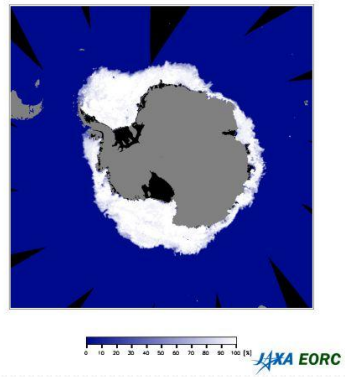
Snow Depth



Soil Moisture Content



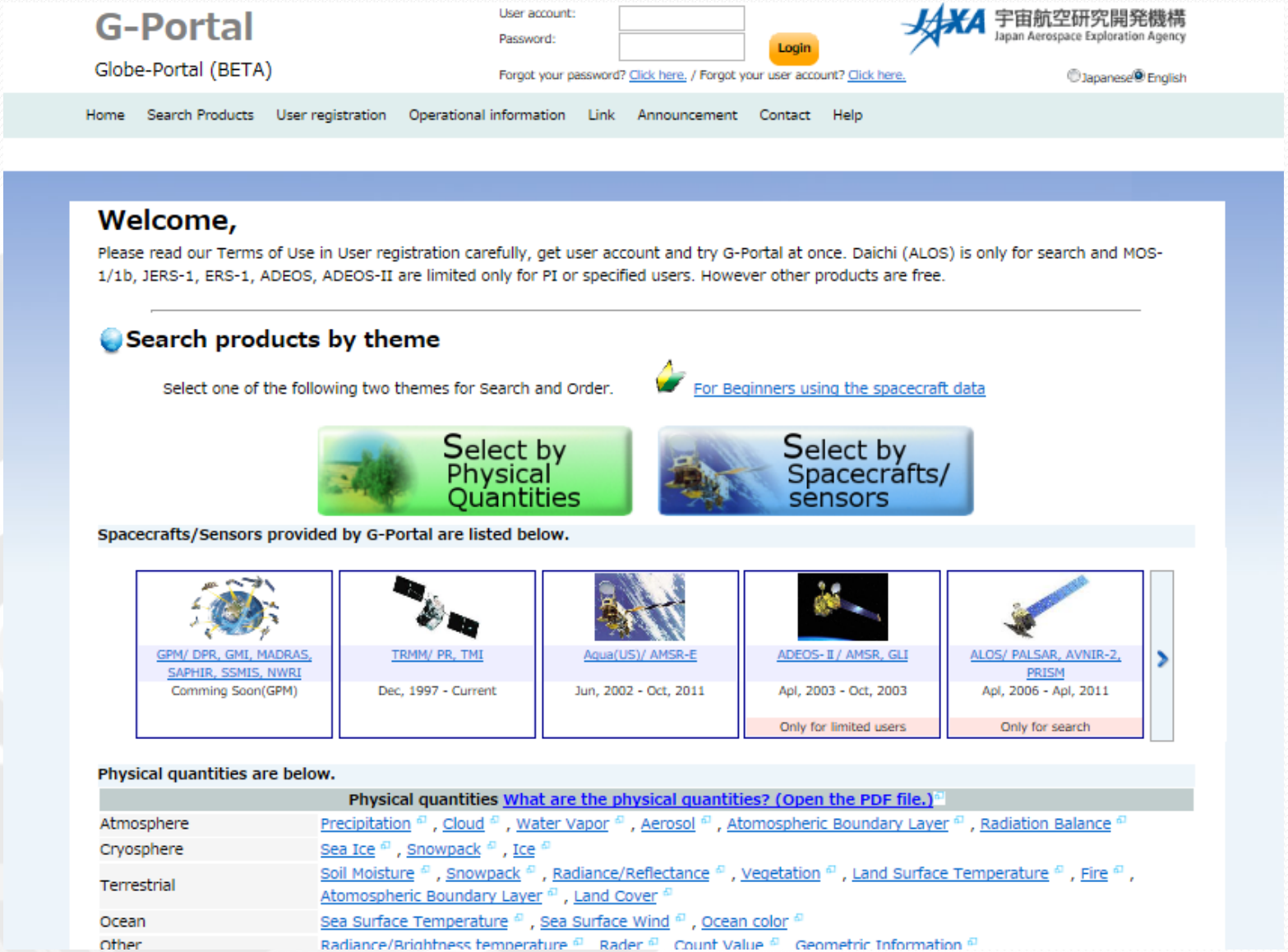
Sea Ice Concentration



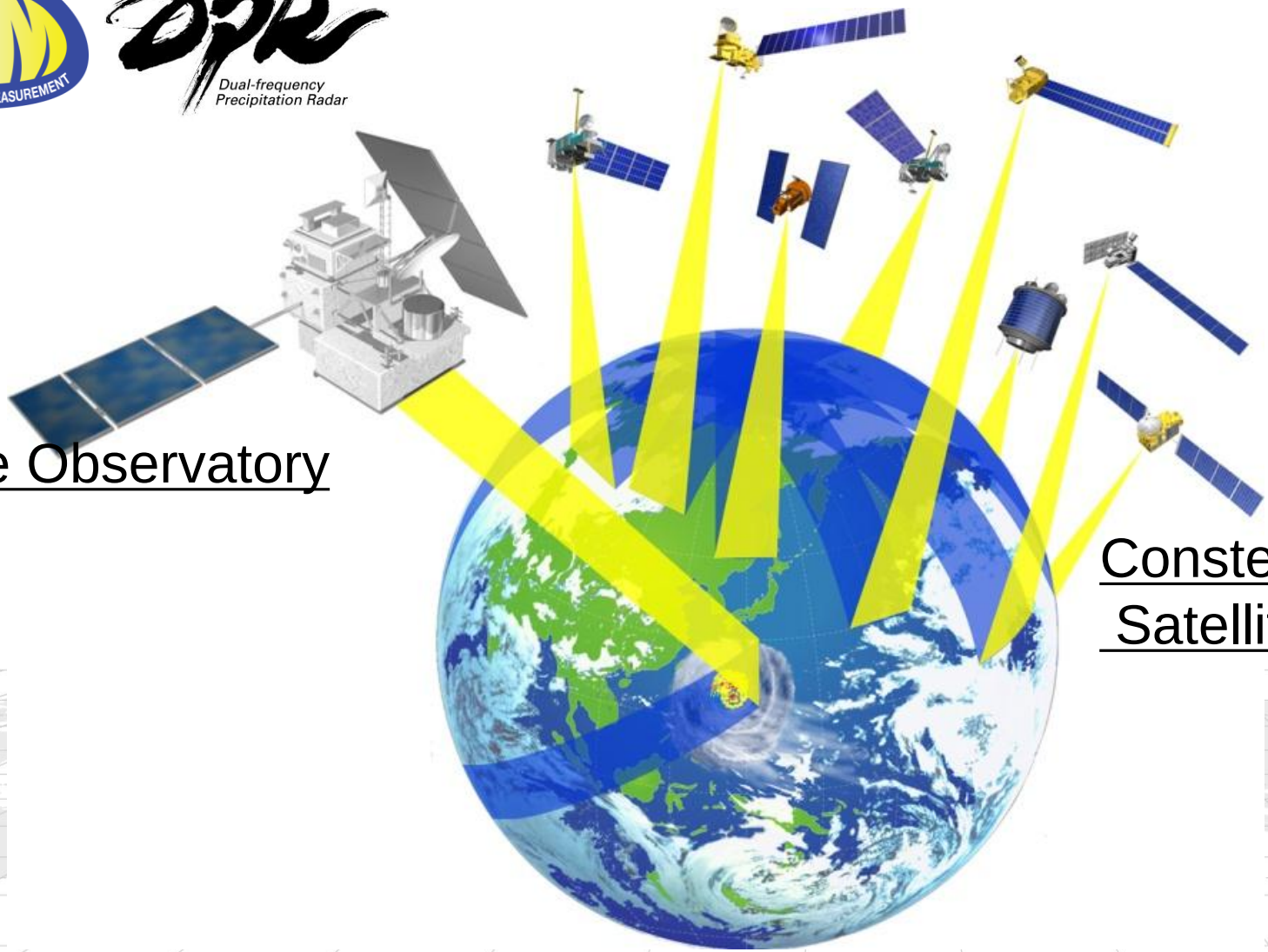
8 May 2013, Descending orbit

Globe Portal (G-Portal)

https://www.gportal.jaxa.jp/

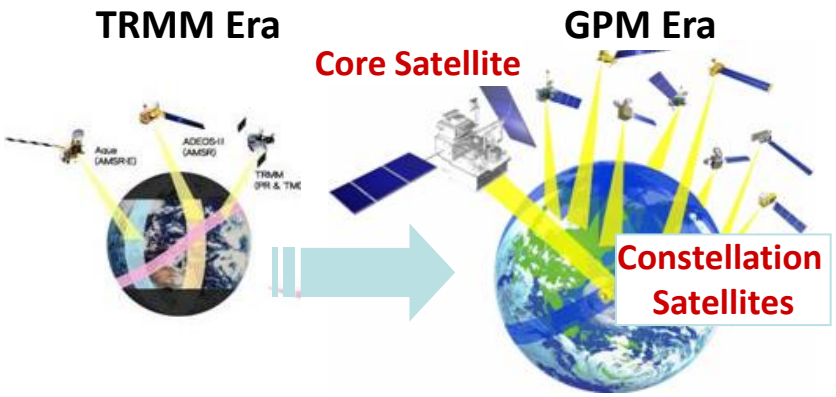


Global Precipitation Measurement (GPM)



Global Precipitation Measurement (GPM)

- GPM: An international satellite mission, which is a follow-on mission of TRMM, to be launched by JAXA and NASA in early 2014 for precipitation measurements worldwide



Core Satellite (JAXA, NASA)

Dual-frequency precipitation radar (DPR)

GPM Microwave Imager (GMI)

- **Precipitation with high precision**
- **Discrimination between rain and snow**
- **Adjustment of data from constellation satellites (The core satellite will fly in non-sun-synchronous orbit.)**

(launch in 2014)

Constellation Satellites (International Partners)

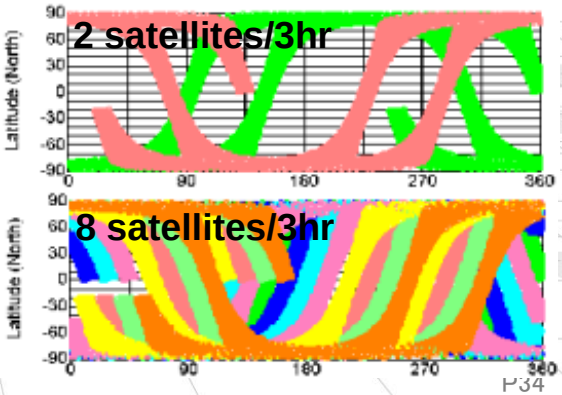
Microwave radiometers

Microwave sounders

- **Global precipitation every 3 hours**

(launch around 2014)

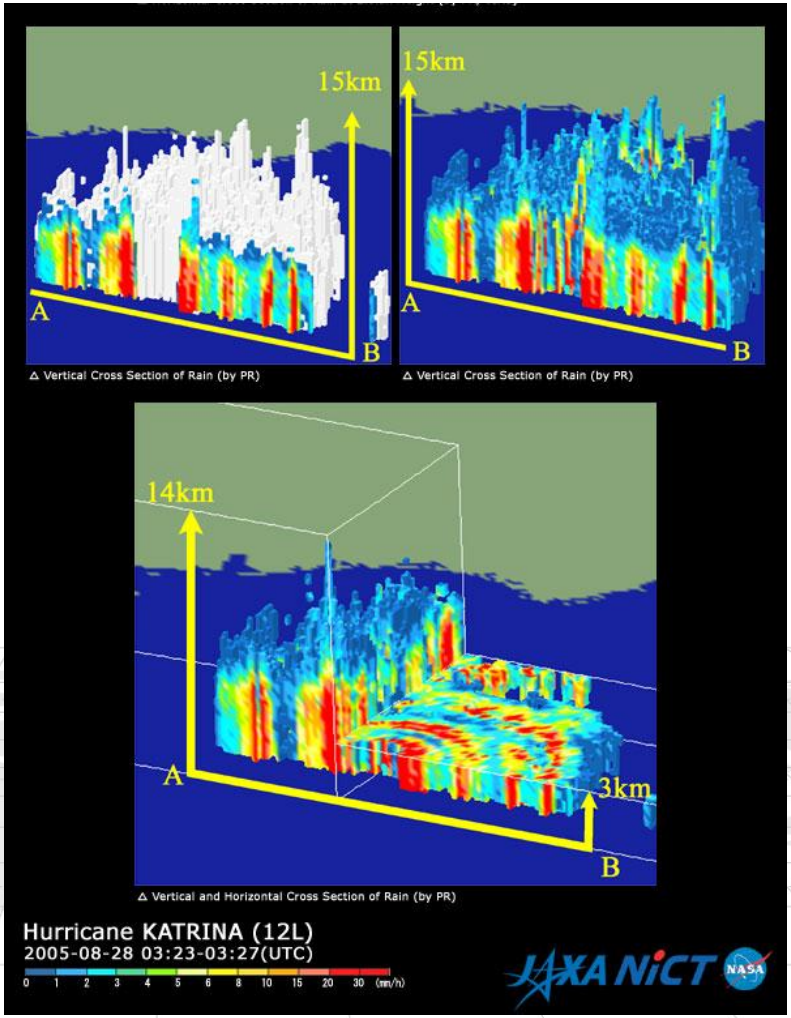
- Improve the accuracy of both long-term and short-term weather forecasts
- Improve water resource management in river control and irrigation systems for agriculture



Precipitation Radar (PR) onboard TRMM

- The GPM is an expanded mission of the Tropical Rainfall Measuring Mission (TRMM).
- TRMM was launched in 28th Nov. 1997 and continues observation over about 15 years since its launch.
  - TRMM is expected to overlap with GPM Core satellite.
- The first spaceborne Ku-band precipitation radar (PR) developed by JAXA and NICT was installed on TRMM.

Hurricane Katrina hit the southern coastal area of the United States on August 29, 2005.

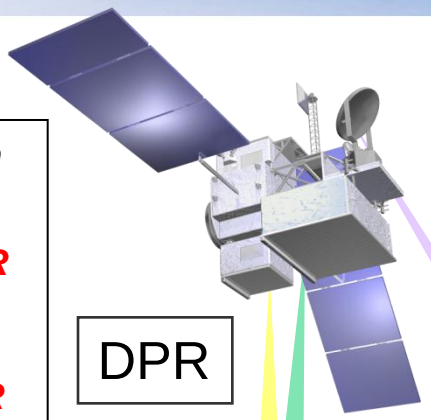


“DPR” aboard GPM core satellite

(launch in 2014)

Dual-frequency precipitation radar (DPR) consists of
-Ku-band (13.6GHz) radar : KuPR
(similar to TRMM/PR)
and
-Ka-band (35.5GHz) radar : KaPR

The DPR was developed by JAXA and NICT.



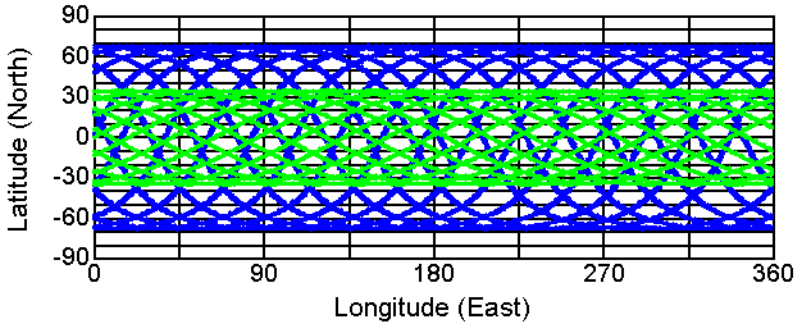
DPR

GMI

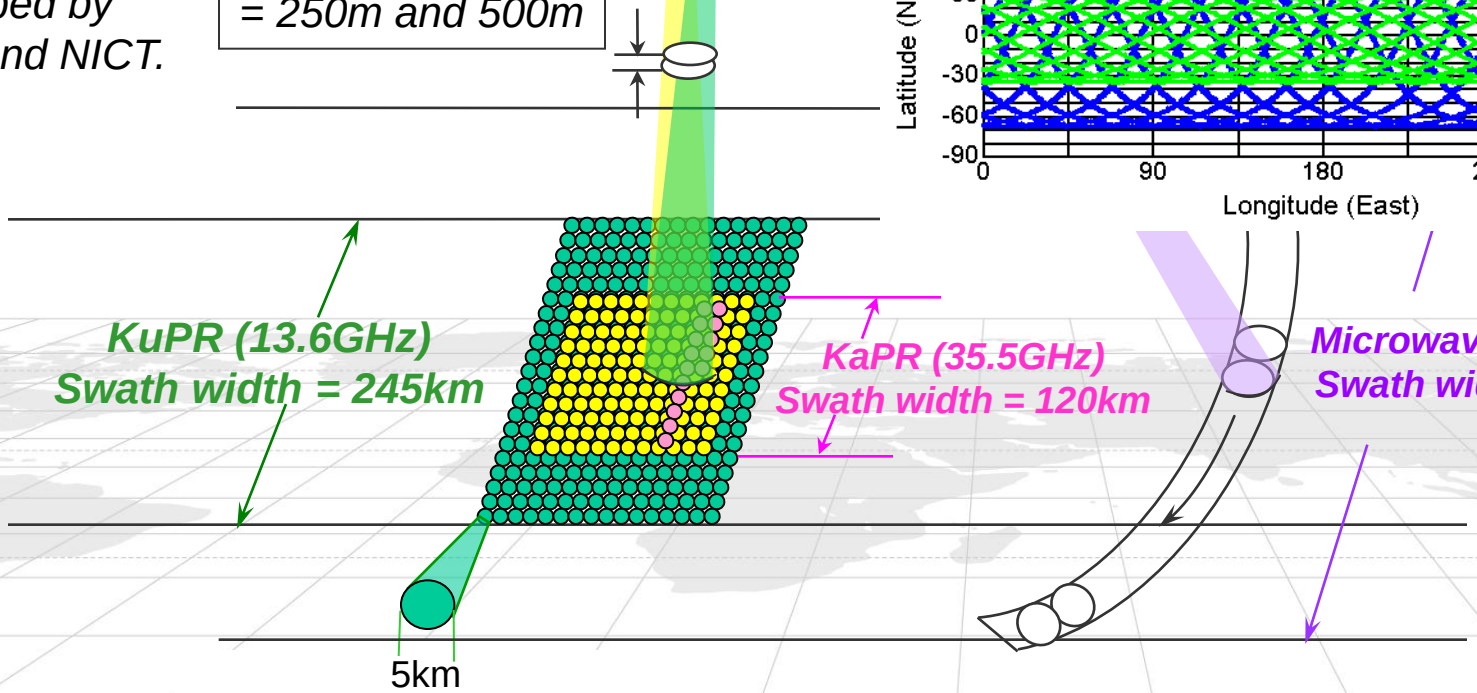
Flight direction

407 km altitude, 65 deg inclination

1-day orbits of TRMM(PR) and GPM-Core(DPR)

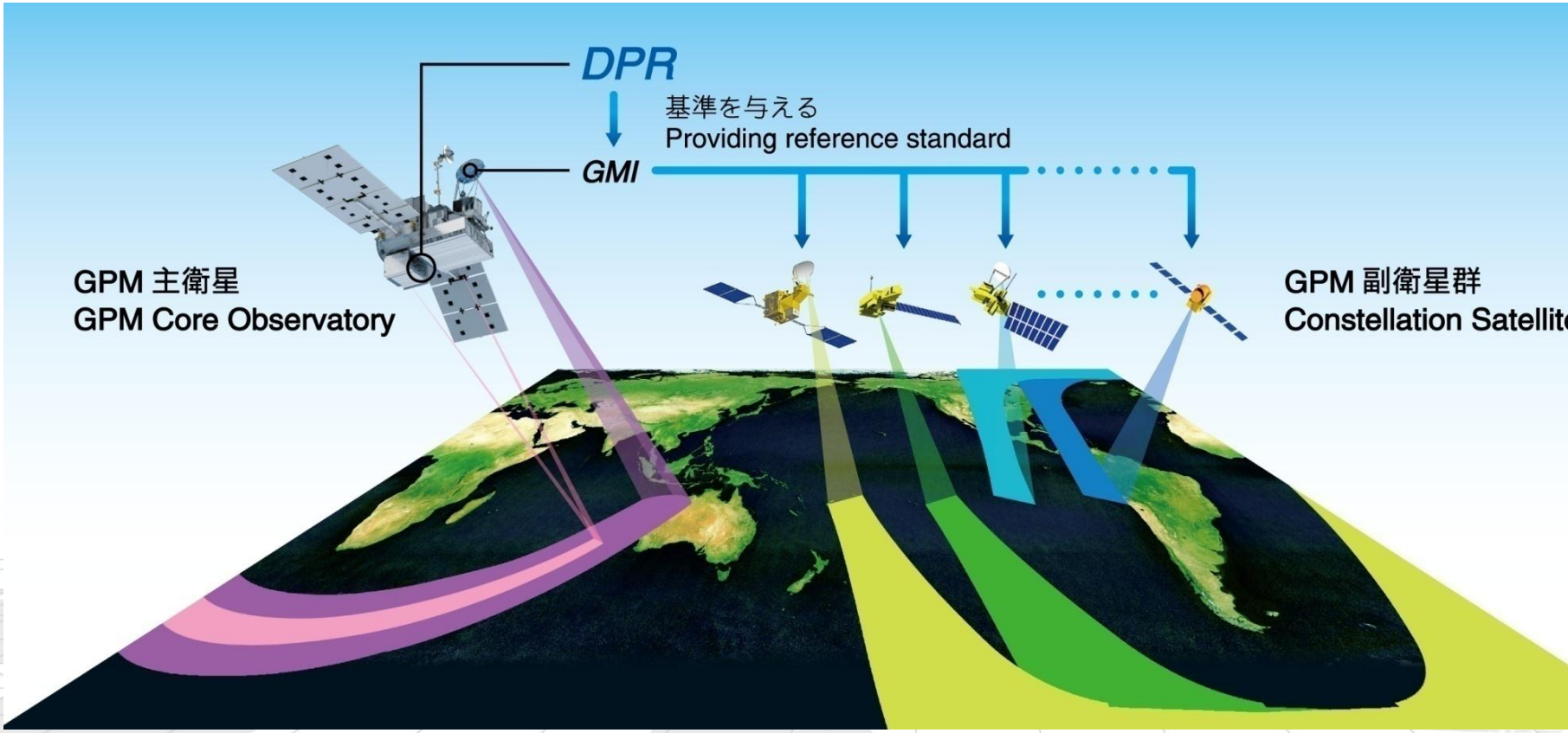


Range resolution = 250m and 500m



DPR: “Reference Standard” of GPM

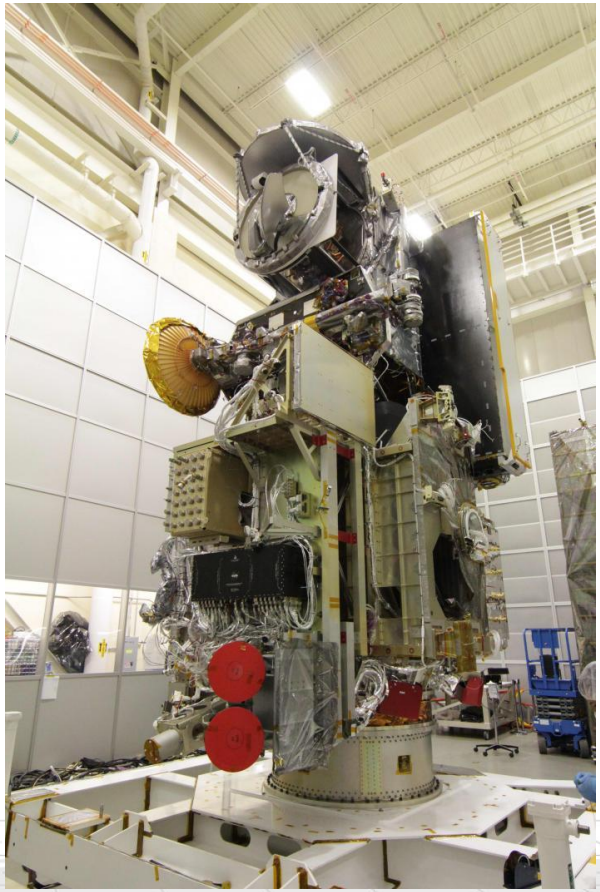
Accurate, High sensitivity, 3D Measurement by Dual-frequency Precipitation Radar (DPR)



DPR will provide “reference standard” of the GSMaP.
The GSMaP is one of JAXA standard product of the GPM.

GPM Core satellite

DPR was shipped from Tsukuba to GSFC on 14 Mar. 2012.



Integration completed in May 2012 at GSFC.

GPM Core satellite has completed thermal vacuum test in Jan. 2013, and continues environmental test at GFSC under collaboration of NASA and JAXA engineers. Satellite will be shipped back to Japan in autumn 2013 for launch.

Summary

- GSMaP
  - The GSMaP is one of JAXA standard product of GPM, and is a product merged from various sensor data from satellites, in addition to other resources (e.g, rain gauges).
  - Brief algorithm flow & Validation
  - Recent progress
    - Improvements in sampling of observation for rainfall
    - We **completed** the re-processing with the period during Mar. 2000- Nov. 2010. to registered users.
    - Released text version of re-analysis data in GIS format (Oct. 2012) due to many requests from flood community.
    - Test version of GSMaP gauge-calibrated GPM product was released for limited users for evaluation. (Nov. 2012)
    - Gauge-caribrated GSMaP (GSMaP_Gauge) with the period during Mar. 2000-Nov. 2010 will be open soon!
    - Web site renewal (Jun. 2013), New GSMaP logo
    - Introduction of GCOM-W1/AMSR2 (in preparation).

Summary

- GCOM-W1/AMSR2
  - Launched on May 17, 2012 (JST) from Tanegashima Space Center.
  - L1 and L2 products are publicly released.

- GPM/DPR
  - The GPM is an expanded mission of the TRMM and the mission for precipitation measurements worldwide
  - DPR will provide "reference standard" of the GSMaP.
  - Launch of GPM Core satellite is **early 2014**
  - GPM Core satellite is currently tested at NASA GSFC, and will be shipped to Japan in autumn 2013.