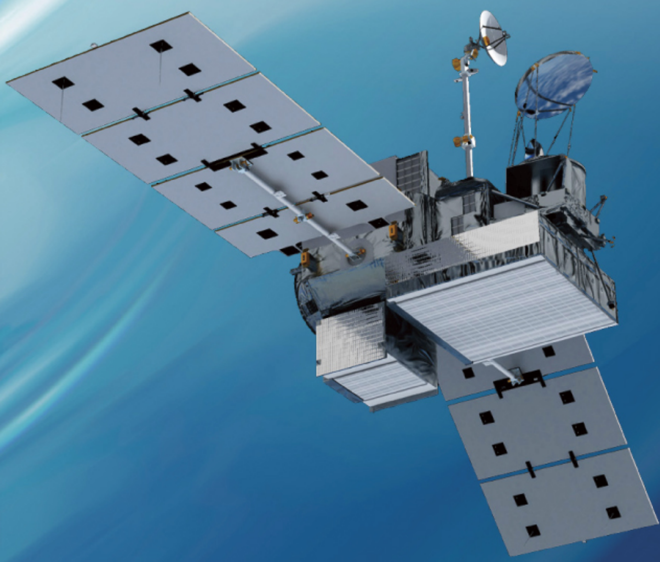
JAXA GPM Science Status

Yukari N. Takayabu (Univ. Tokyo)



AOGS 2017@Singapore on August 2017

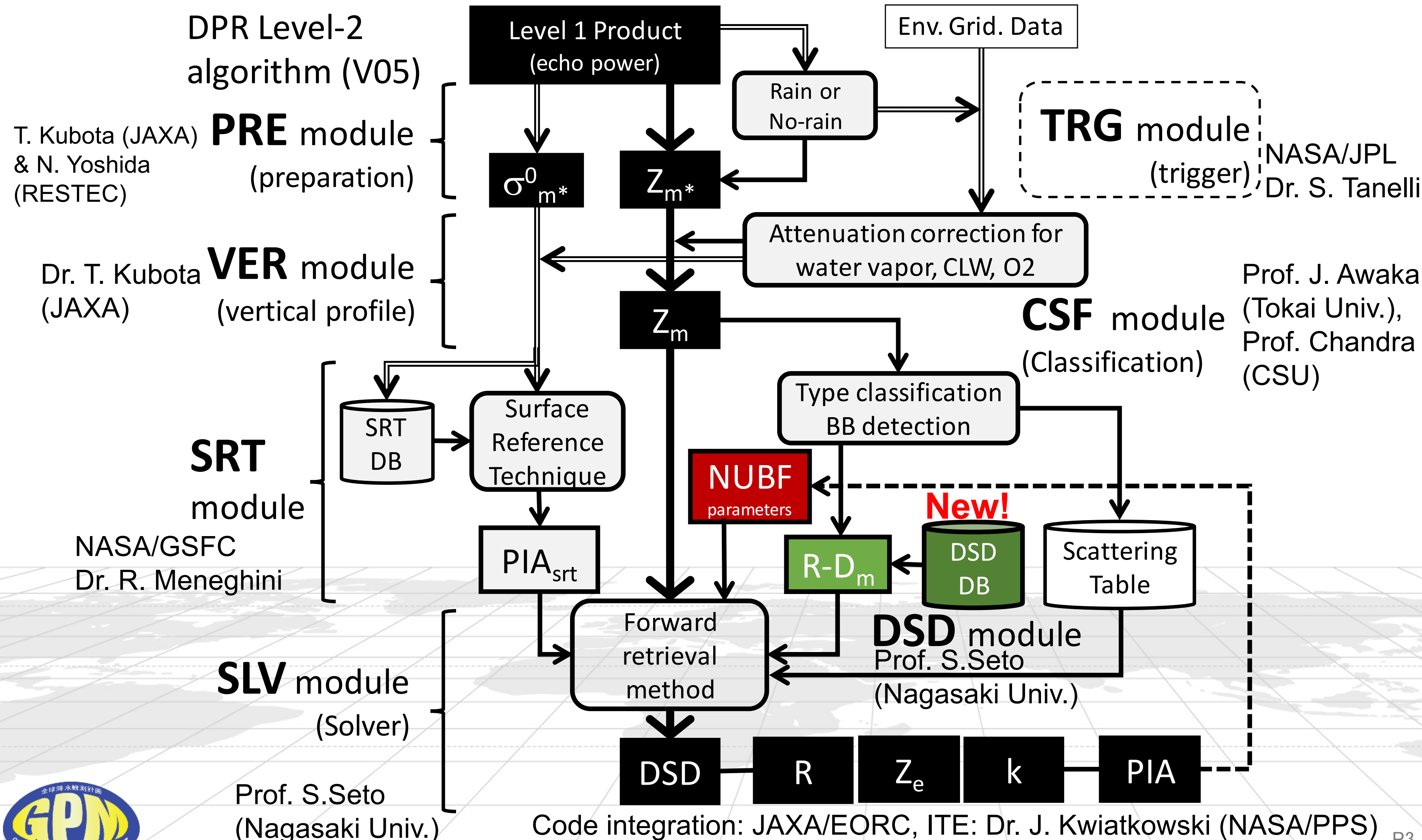
Science team : 41 PIs

- Algorithm developments
- Validations
- Applications

DPR-L2 algorithm development

Main stream is same as KuPR algorithm,
KuPR's Z_m → KuPR's Z_e → DSD & precip
But, several dual-freq methods are introduced
→ Iguchi's presentation

Leader: T. Iguchi (NICT)

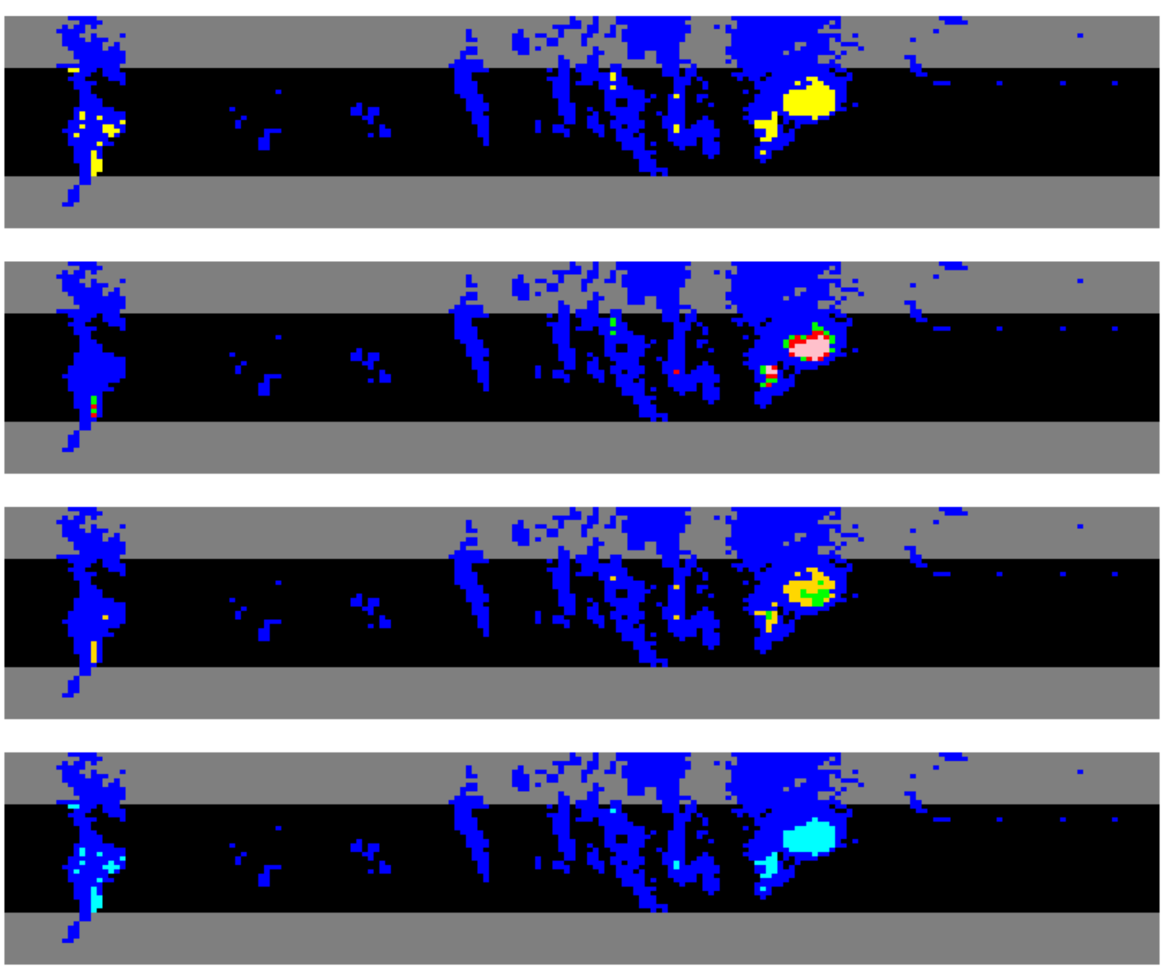


Code integration: JAXA/EORC, ITE: Dr. J. Kwiatkowski (NASA/PPS)

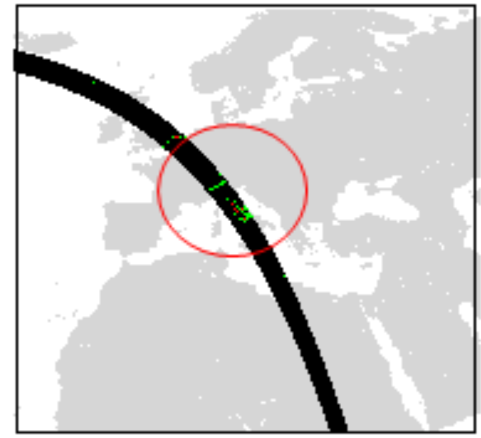
DPR flags for solid precipitation particles: flagHeavyIcePrecip

2015/09/05
Orbit #008630

Only data above the -10 deg C are used to detect HeavyIcePrecip



ITE113



flagHeavyIcePrecip

=

Ku decision

Z(ku) > 45 dBZ
45 >= Z(ku) > 40 dBZ
40 >= Z(ku) > 35 dBZ

+

Ka decision

Z(ka) > 40 dBZ
40 >= Z(ka) > 35 dBZ
35 >= Z(ka) > 30 dBZ

+

DFRm decision

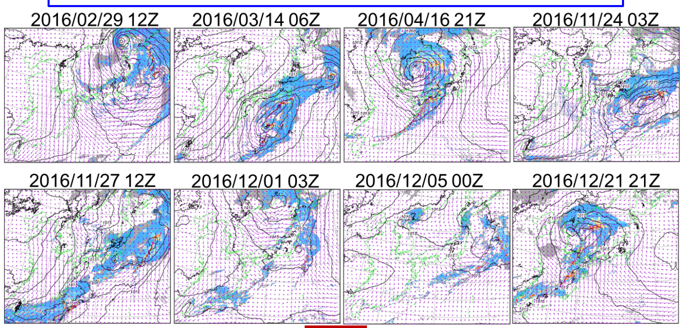
Z(ku) > 27 dBZ and DFRm > 7 dB

In the Classification (CSF) Module, Awaka introduced new flags;
(1) HeavyIcePrecip ,
(2) Anvil Precip and
(3) SurfaceSnowfall

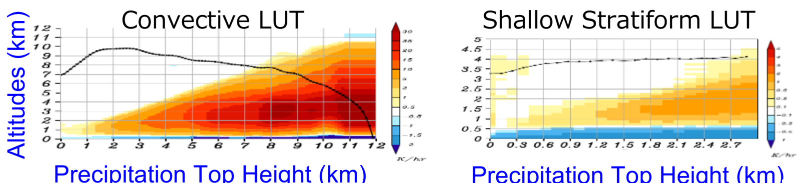
Spectral Latent heating (SLH) V05: Retrieval of Mid-latitude LH Using GPM DPR

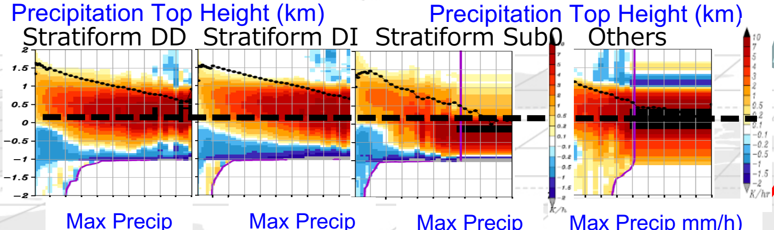
PI: Yukari Takayabu
C. Yokoyama, A. Hamada, T. Ikuta

8 Extratropical Cyclone cases
Simulated with JMA LFM

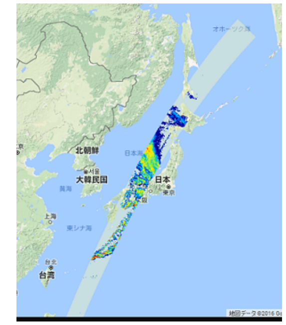


LH Look Up Tables : Precip→LH

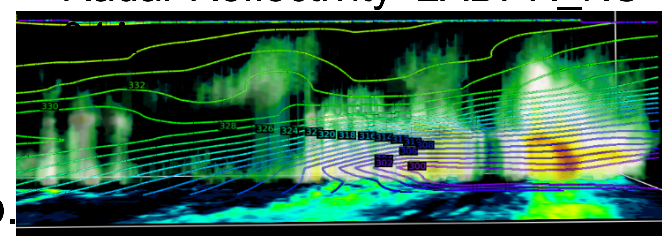




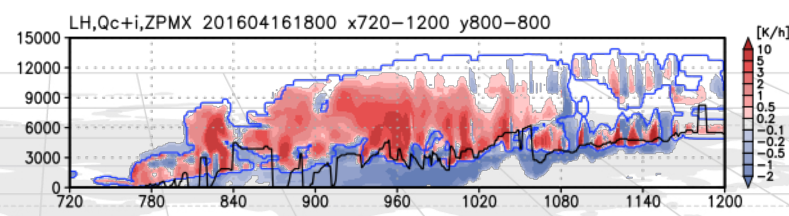
We extended SLH algorithm to the mid-latitudes using simulations with JMA Local Forecast Model (LFM)



Radar Reflectivity 2ADPR_NS



Input GPM KuPR-precip.

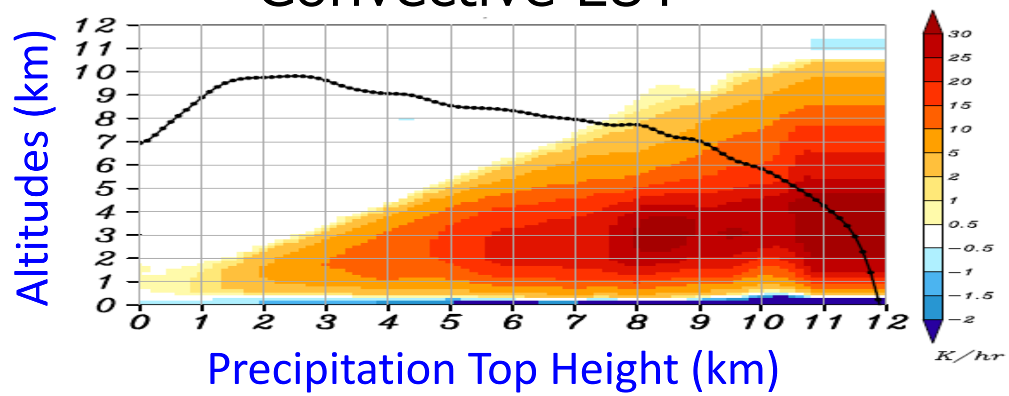


output

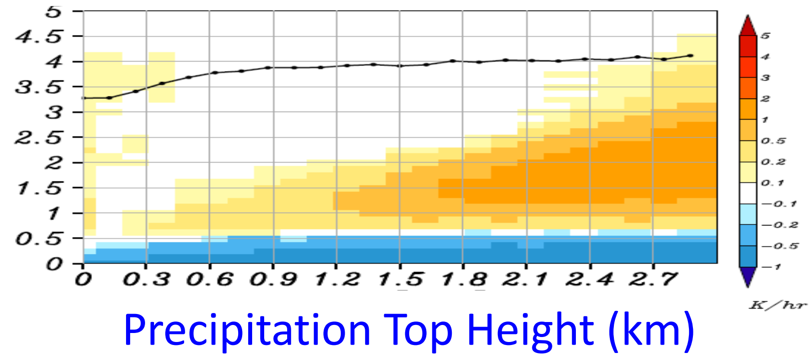
LH, Q1-QR, Q2

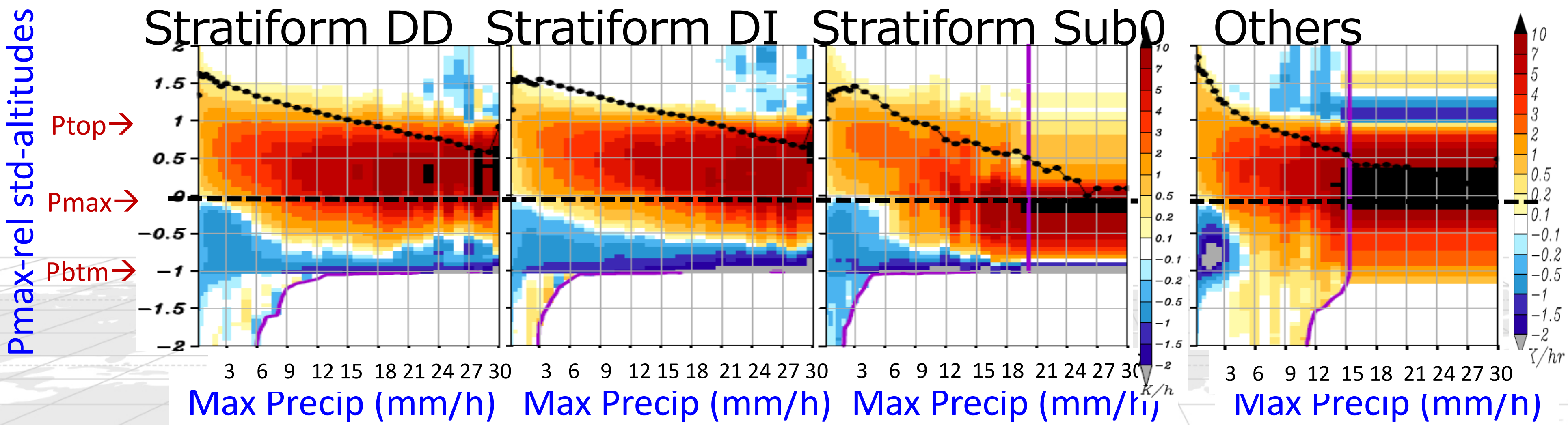
Look-Up Tables for Latent Heating

Convective LUT

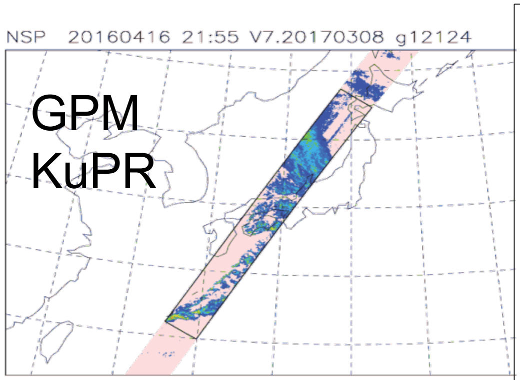


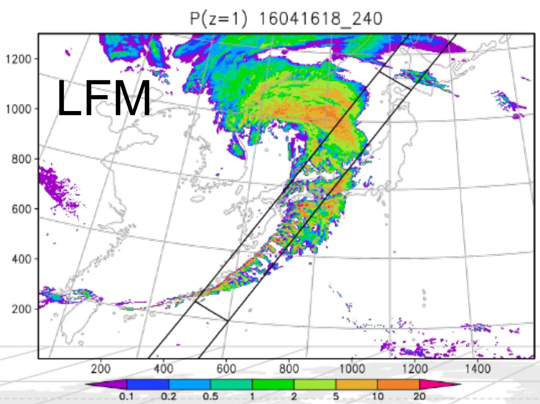
Shallow Stratiform LUT





Average Profiles of LH : 18z 16Apr, 2016





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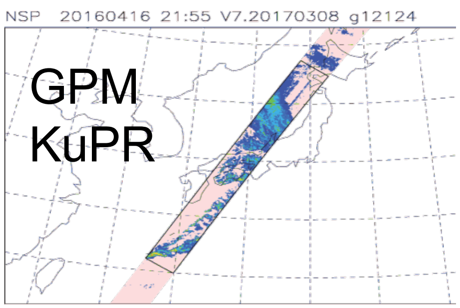
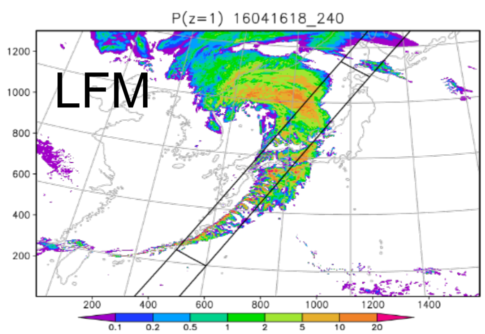
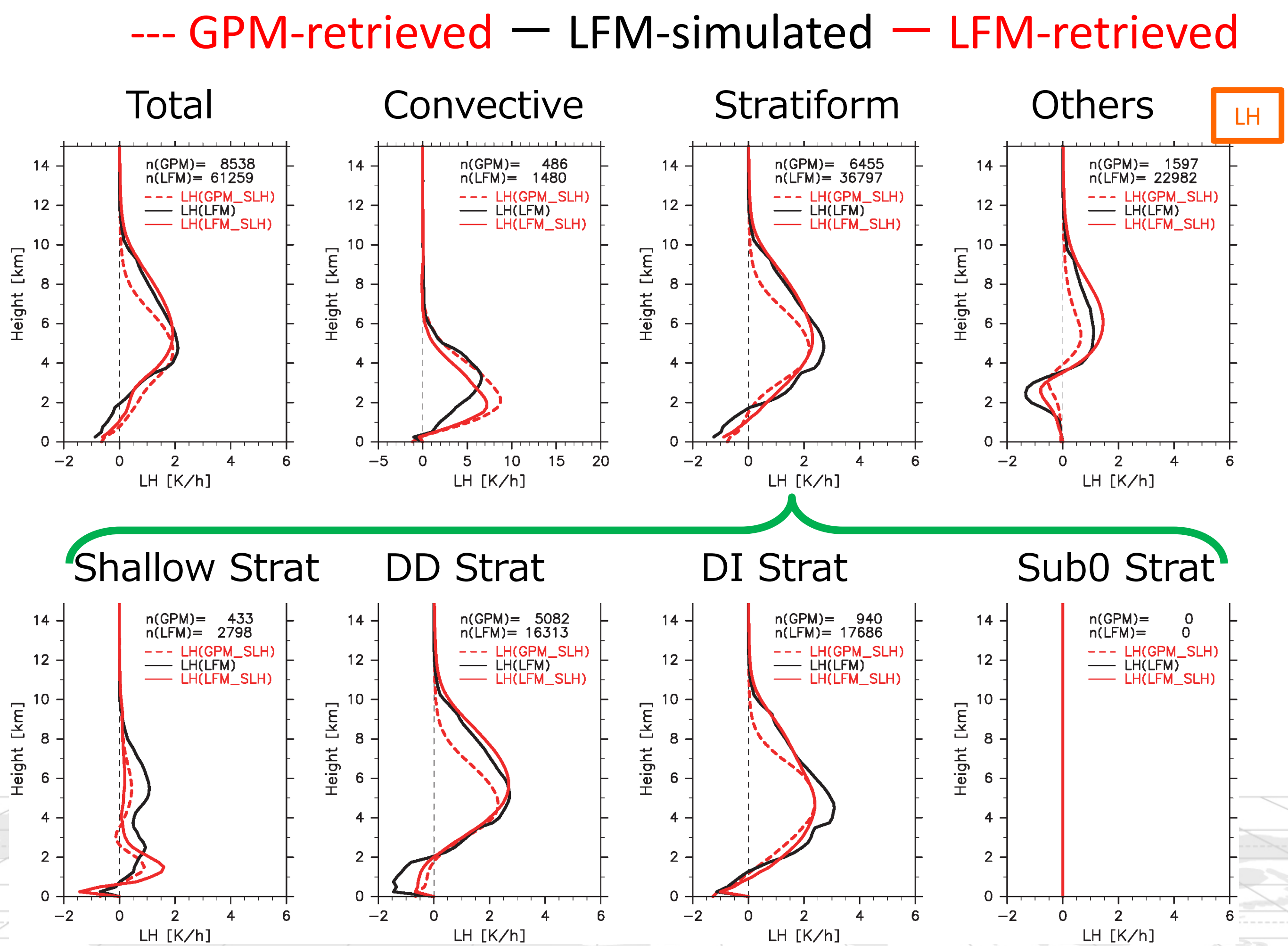
Utilizing GPM KuPR orbital data as an input, we calculated the three dimensional latent heating in pixel basis.

Average Profiles of LH : 18z 16Apr, 2016

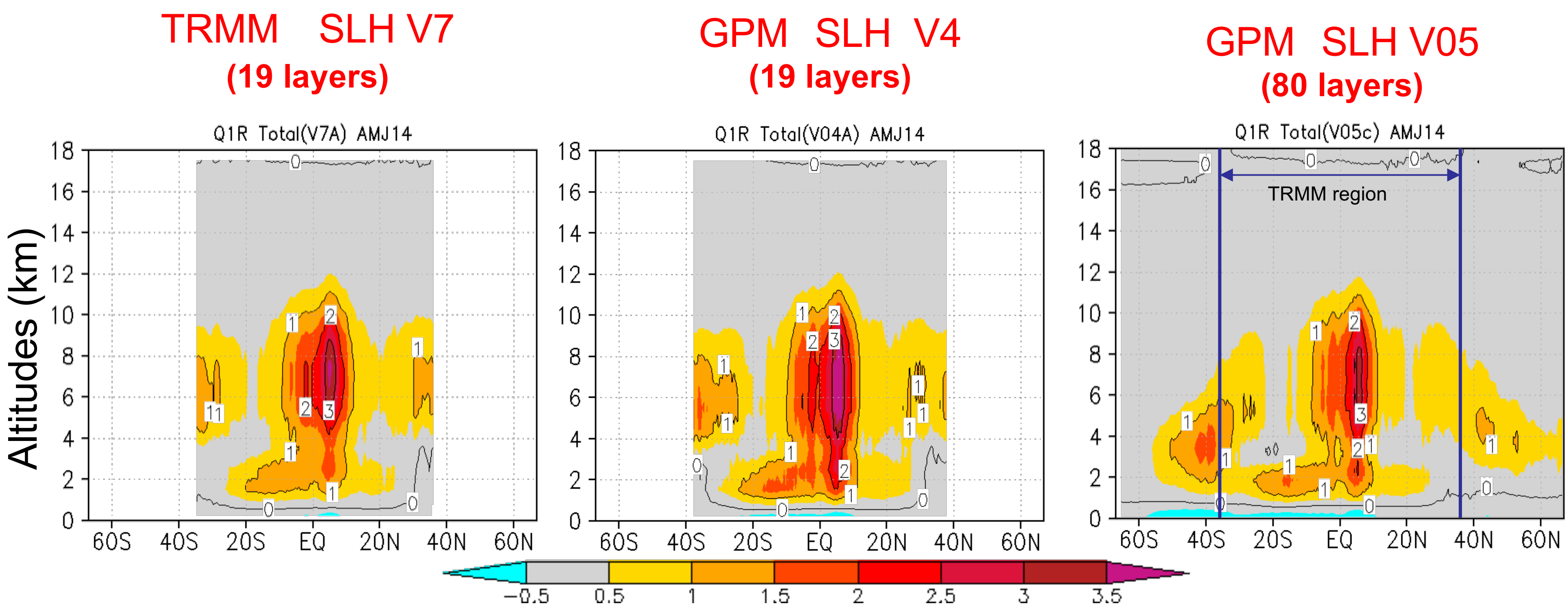






GPM retrieved and LFM-simulated LH profiles averaged in this region coincide very well for total and all precipitation types, separately.

Zonal mean Q1-QR vertical profiles : AMJ2014

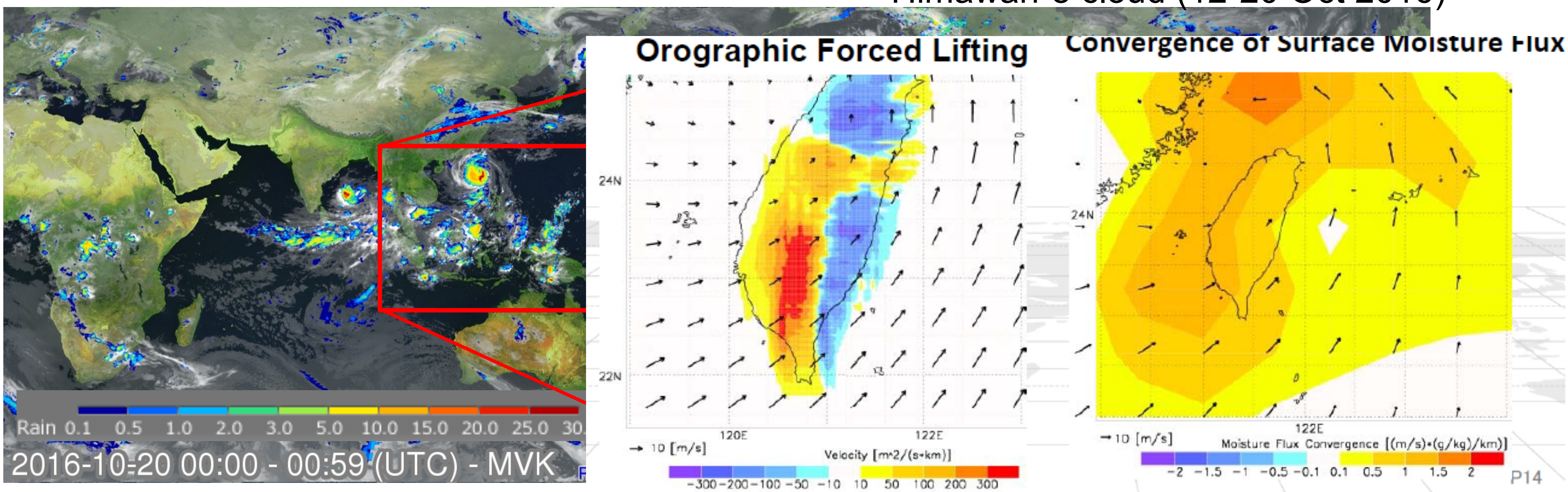


A good consistency in vertical profiles of Q1-QR is confirmed in the TRMM region. Mid-latitude heating profiles smoothly connect to the tropical profiles. Shallow heating in the tropics are retrieved more clearly in V05, due to an increase of the layer number.

Global Satellite Mapping of Precipitation (GSMaP)

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

GSMaP_NRT hourly rain with Himawari-8 cloud (12-20 Oct 2016)

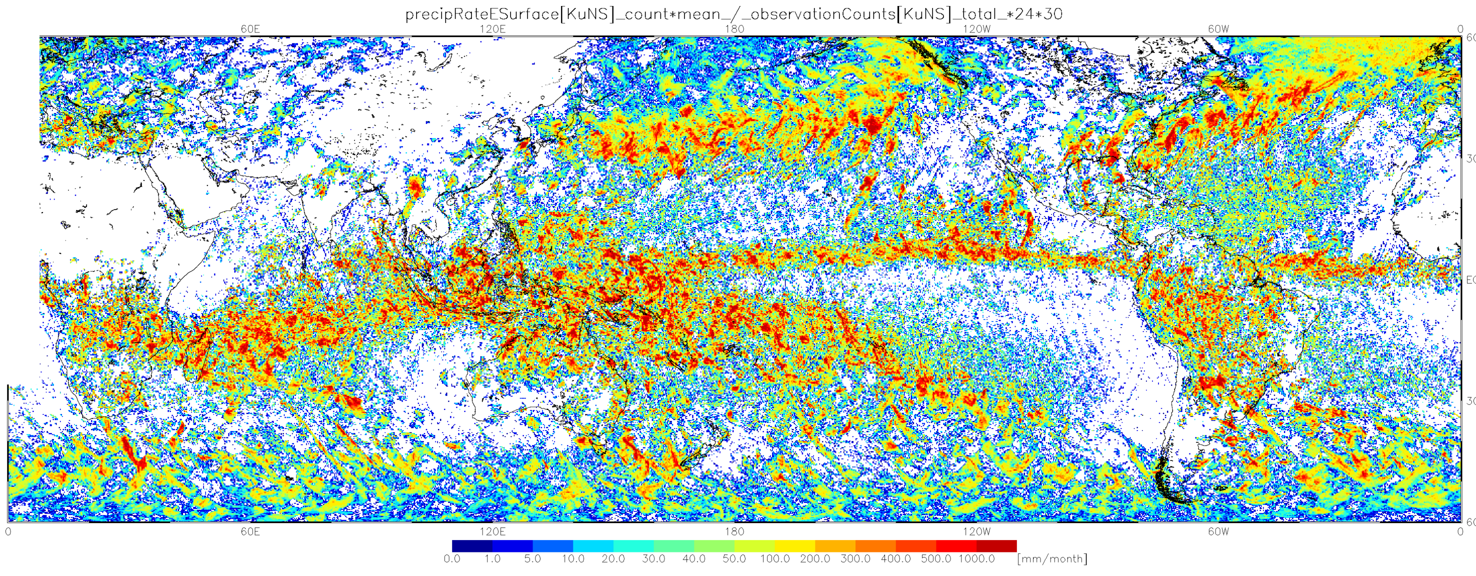


- **Update of GSMaP algorithms**
  - **Improvements in microwave imager algorithm based on AMSR2 precipitation standard algorithm, including new land algorithm, new coast detection scheme, etc.**
  - **Improvements in orographic rainfall correction method for warm rainfall in coastal area** (*Taniguchi et al., 2013, Shige et al. 2014*)
  - **Update of database such as, land surface emission database developed by Japanese DPR/GMI combined team (Drs. Akimoto, Masunaga), etc.**
  - **Development of microwave sounder algorithm over land**

Changes in the GSMaP new version released on January 2017

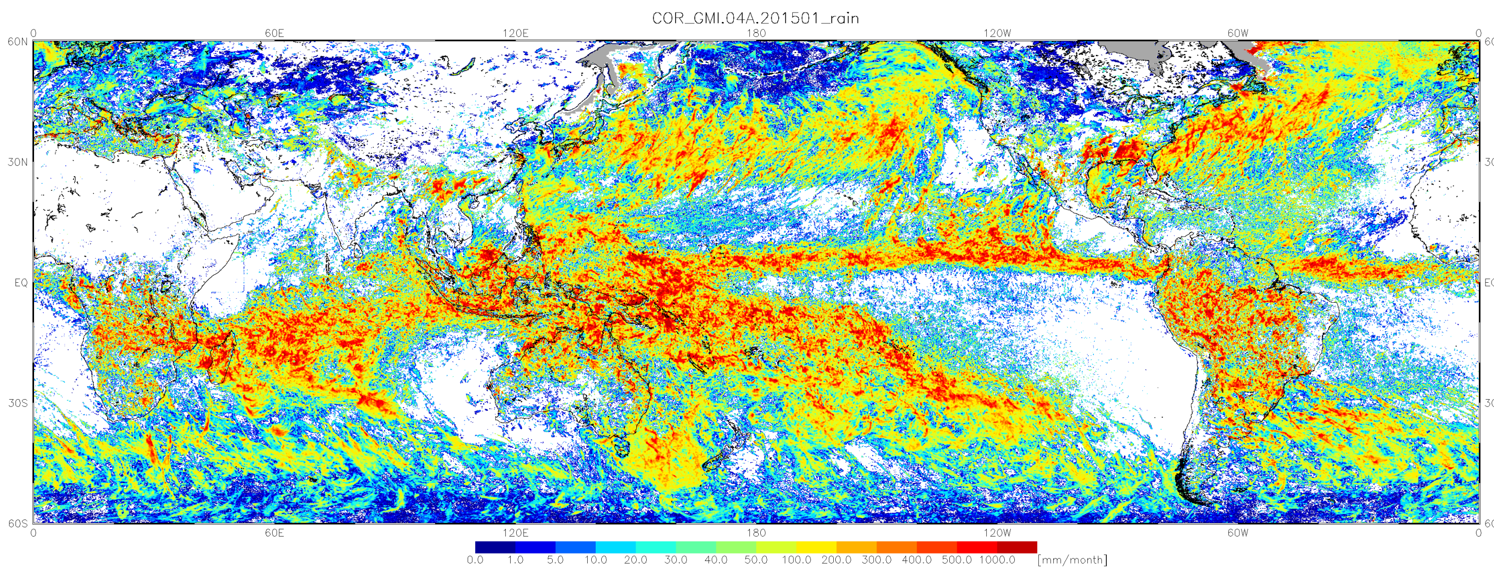
- Surface precipitation amount of the GPM/KuPR product on Jan. 2015

Horizontal pattern of the GSMaP_GMI v7 retrievals were similar to that of the GPM/DPR.



GSMaP_GMI v7 (Jan 2015)
with a snowfall estimation method by Prof. G. Liu (FSU)

- There were detections of snowfall in the Western Eurasian Continent and North-West American Continent

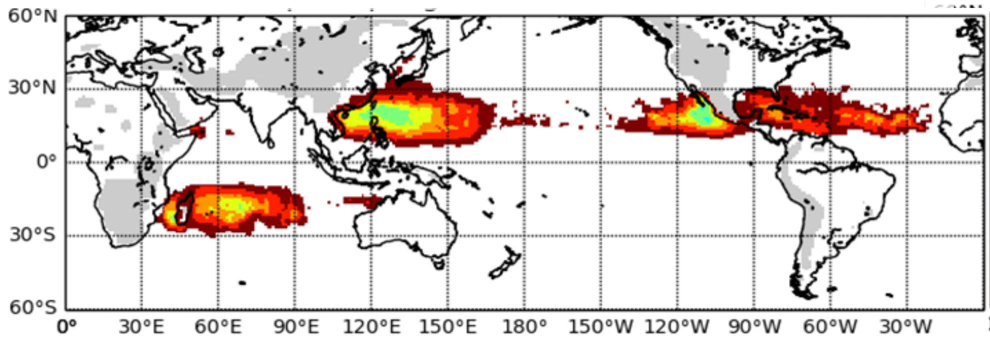


VALIDATIONS

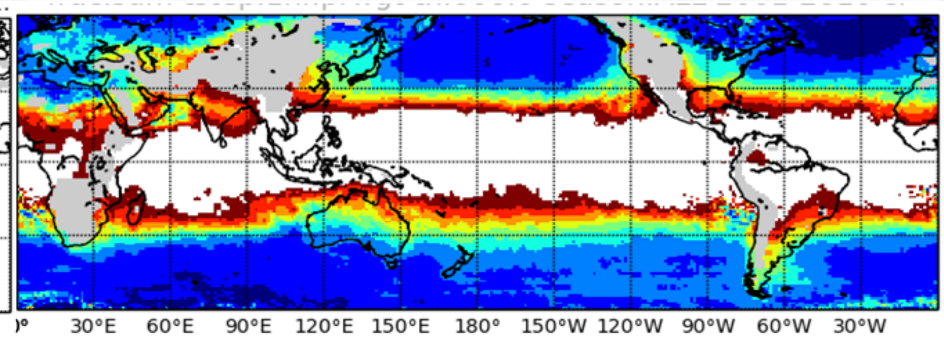
Precipitation by Different Weather Systems & Uncertainty

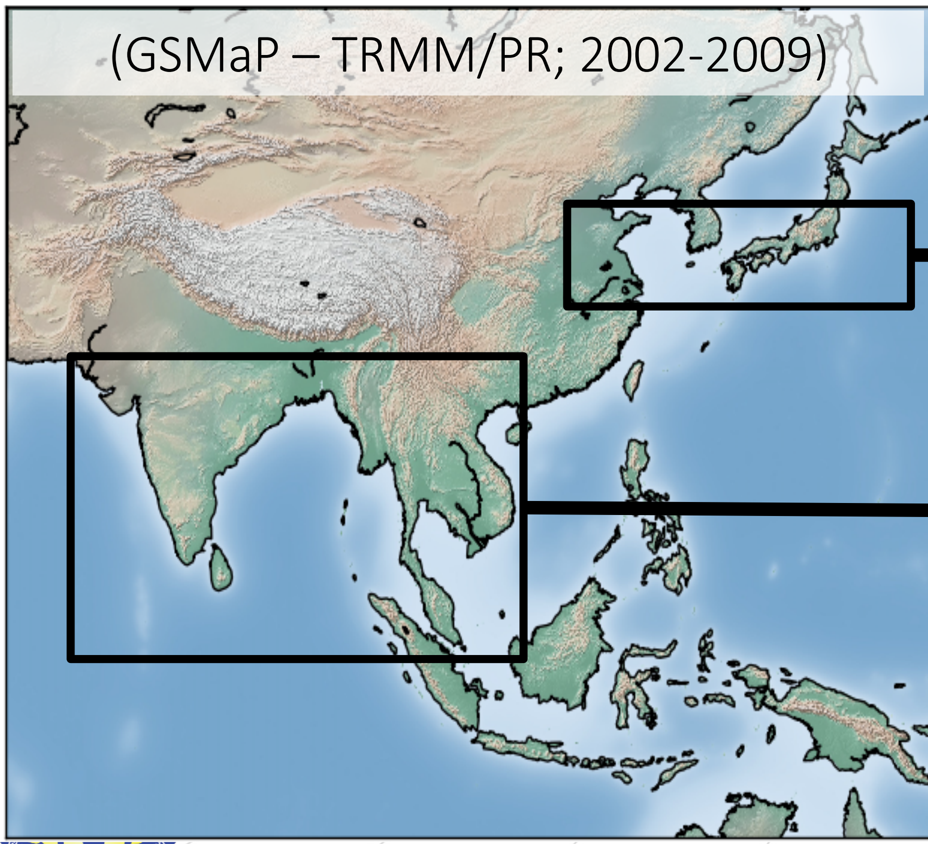
by Kim (Univ. Tokyo)

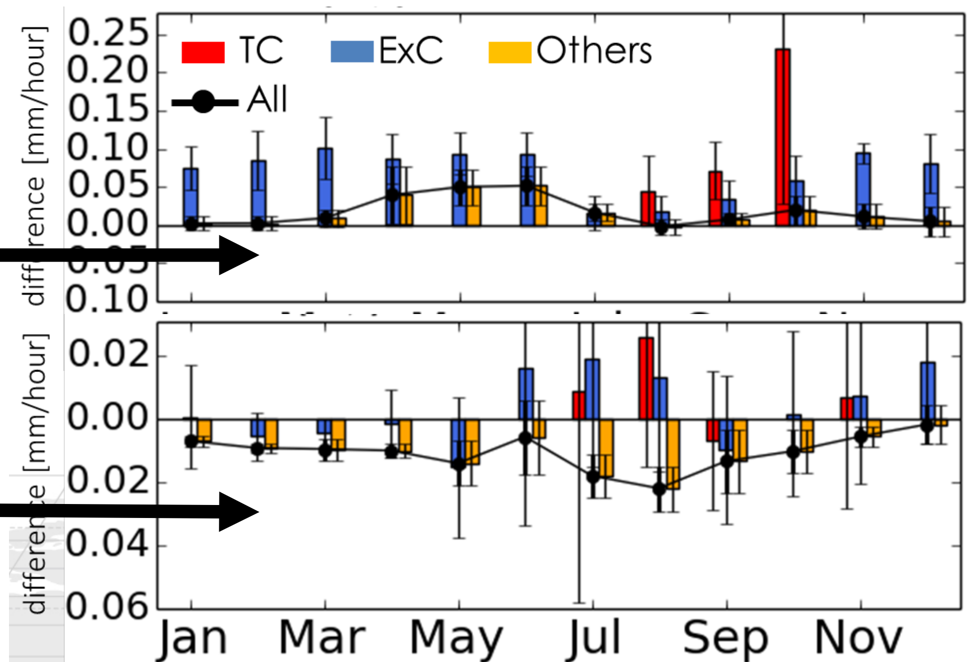
Tropical Cyclone (TC)



Extratropical Cyclone (ExC)







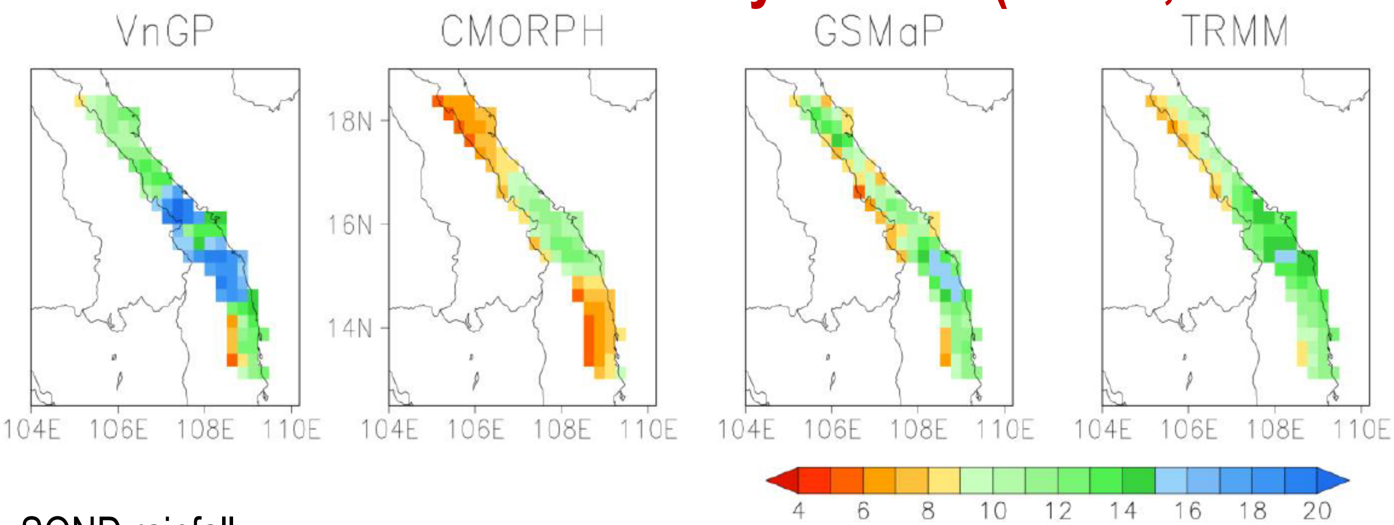
Different biases for …

Regions, seasons, and weather systems

Comparisons of CMORPH, TRMM and GSMaP with station-based gridded rainfall data set in Vietnam (VnGP) :

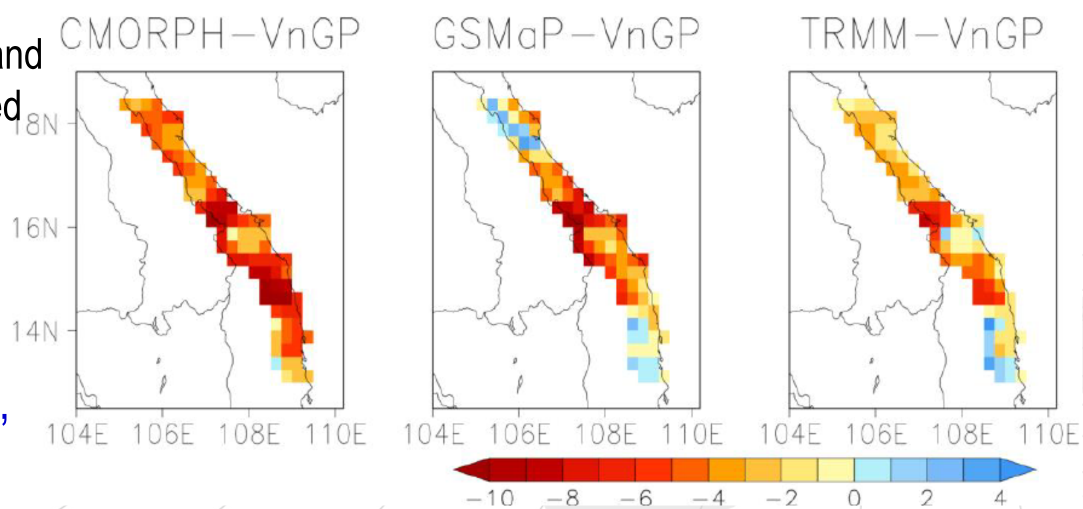
by Matsumoto (TMU

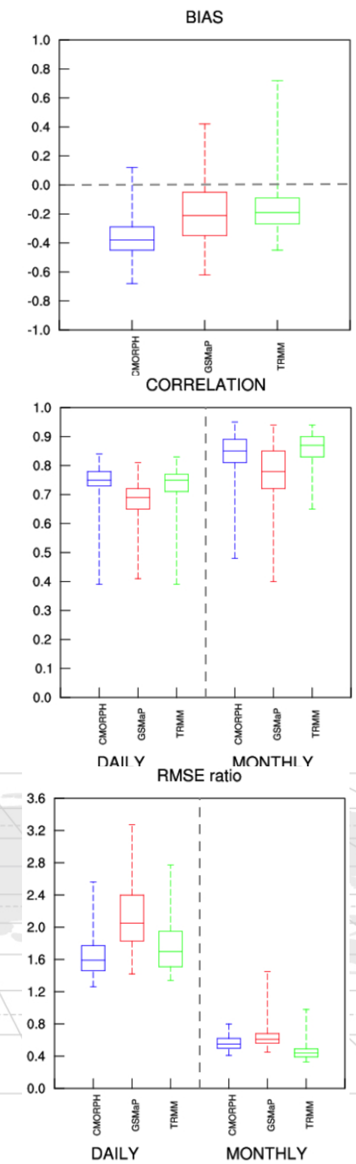
Central Coast in autumn rainy season (SOND, 2001-2010)



SOND rainfall average in VnGP and the 3 satellite-based data (above) and rainfall anomalies (below) relative to VnGP (mmday^{-1})

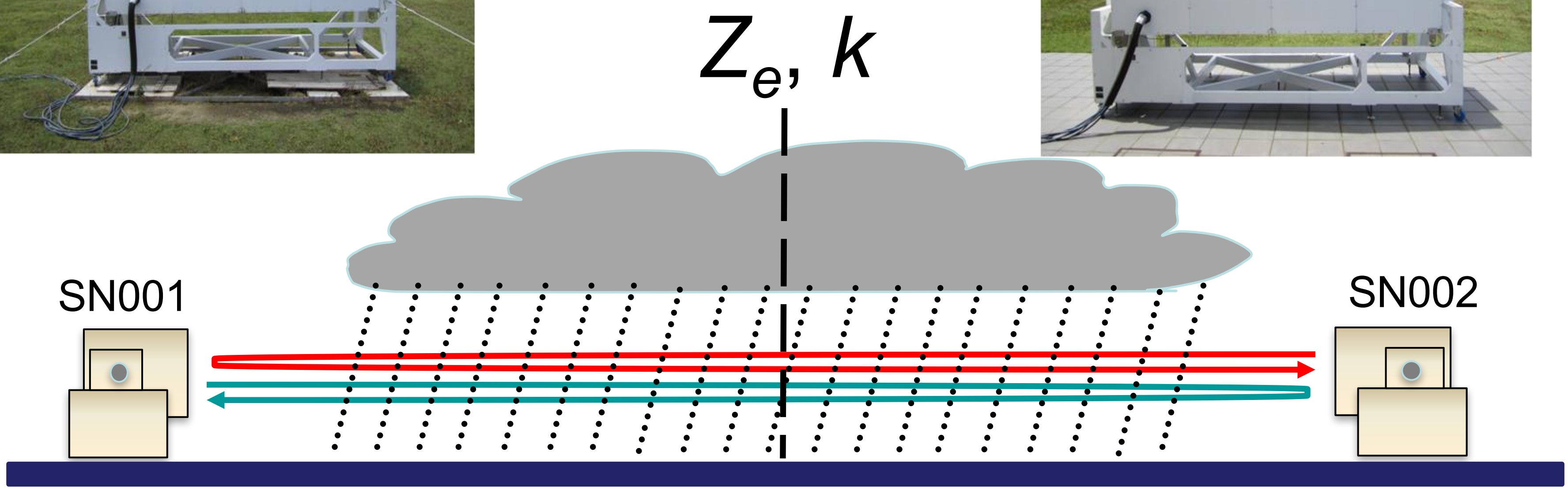
(Trinh-Tuan et al, submitted)





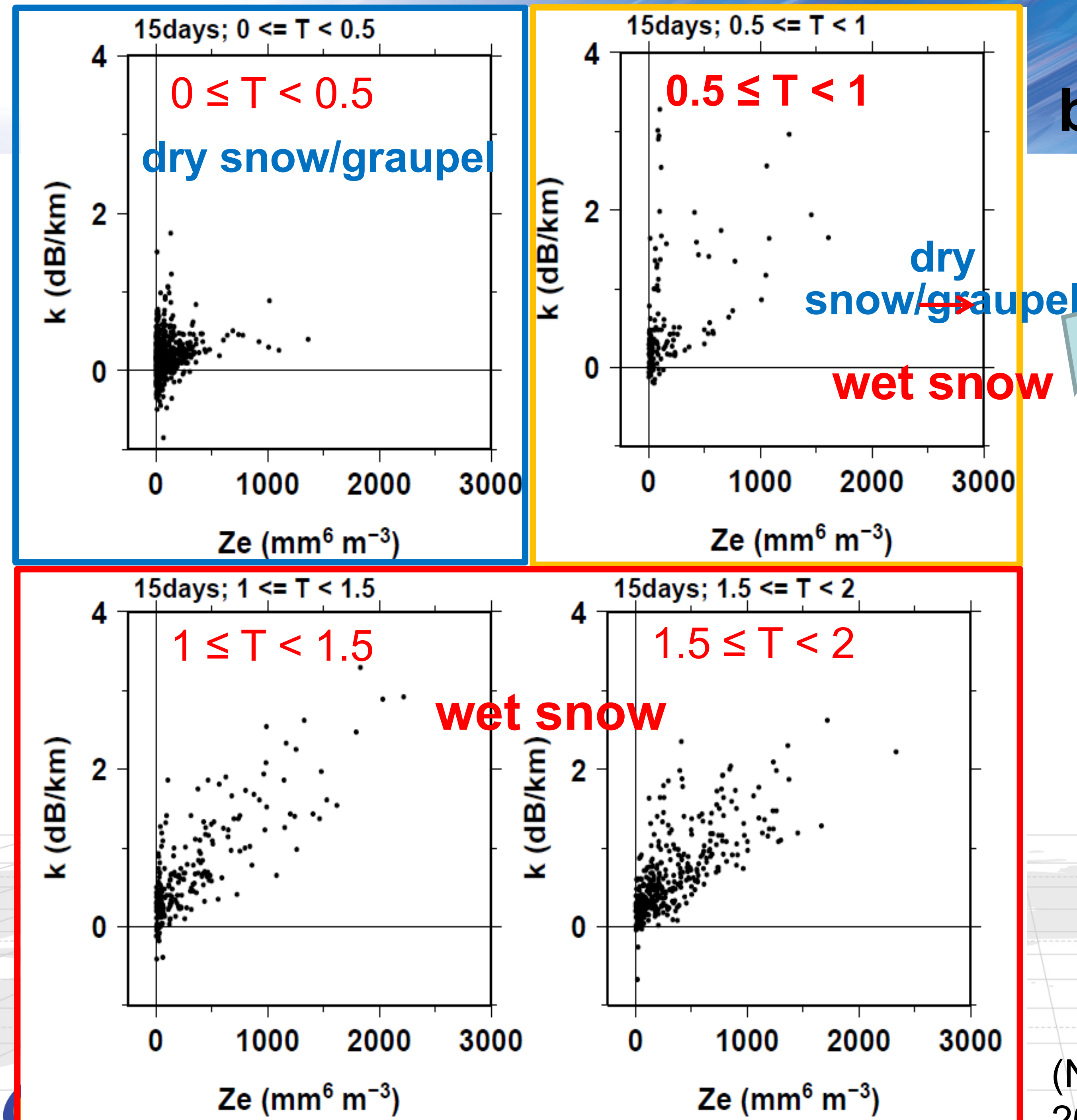
The minimum, P 25th, medium , P 75th and maximum values of bias, CORR and RMSE ratio, corresponding to daily and monthly values at grid scale (right) ｣

Dual Ka-band radar system (JAXA Ka radar)



- Since Z_e and k are measured directly, the uncertainties of these values are reduced.
- Measured k-Z_e relations of rain and snow were already presented

k-Z_e plots by every 0.5 ºC

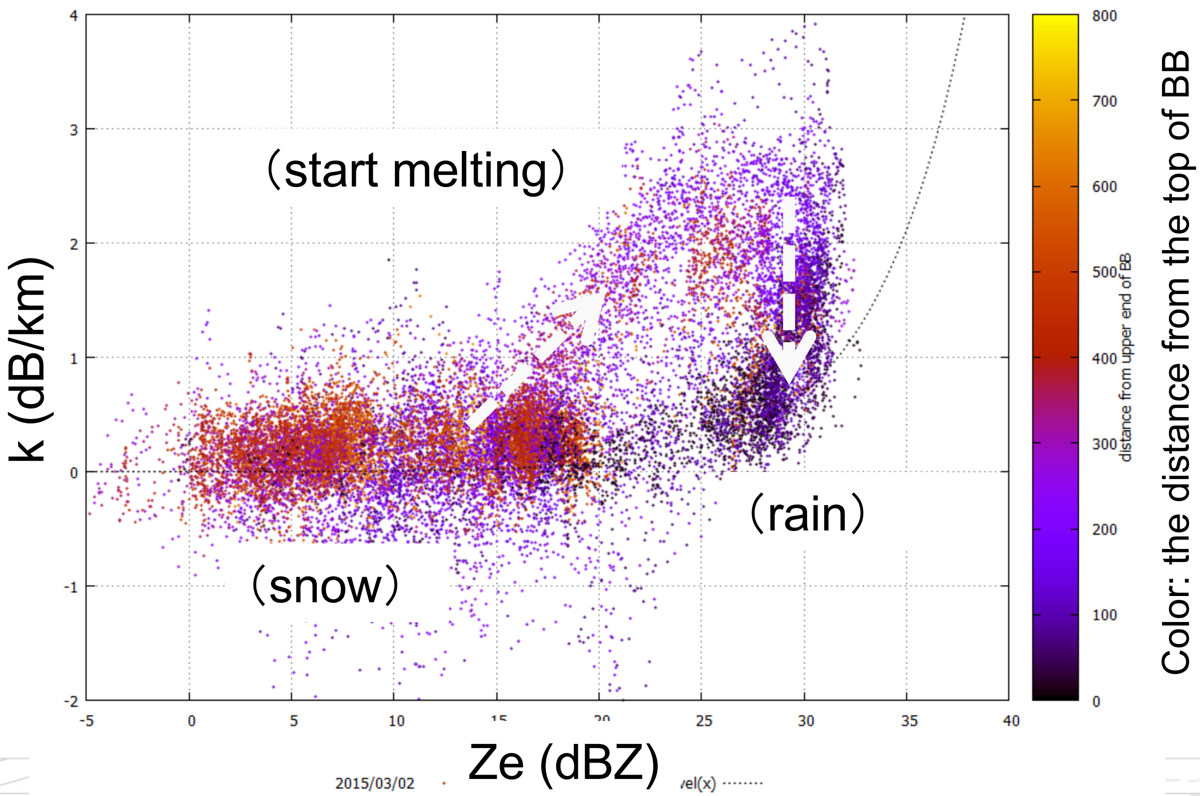


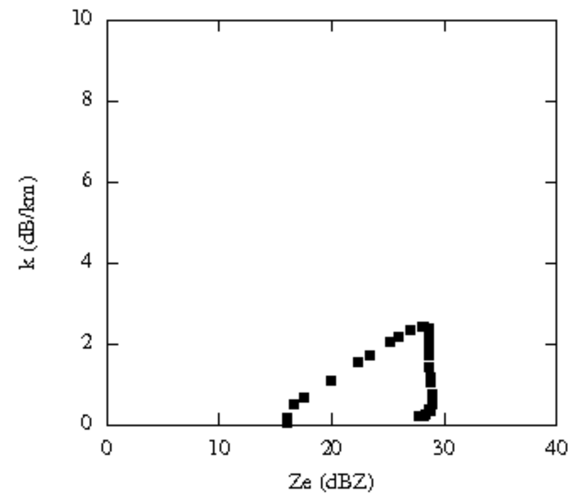
Mean melted fraction approaches to 1. (Thurai and Hanado 2004)

(Nishikawa et al., TGRS, 2015)

Variation of k and Ze during melting

1 Mar, 2015 and 2 Mar, 2015





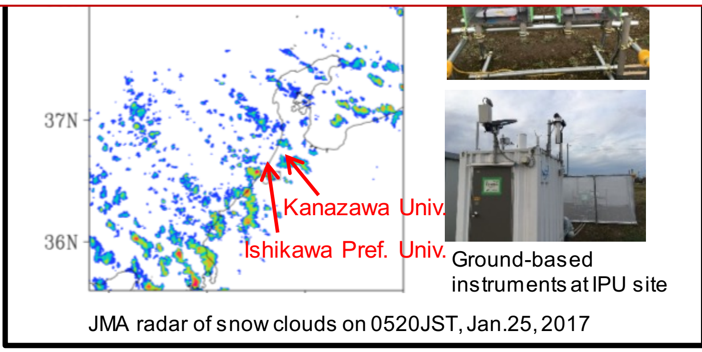
Upper: calculated k and Ze using double-spherical model DSD measured by Parsivel on the ground on 2013/11/26

Measured k and Ze captured a transition from snow to melting phase, and to rainfall. It is qualitatively the same behavior as the theoretical model.

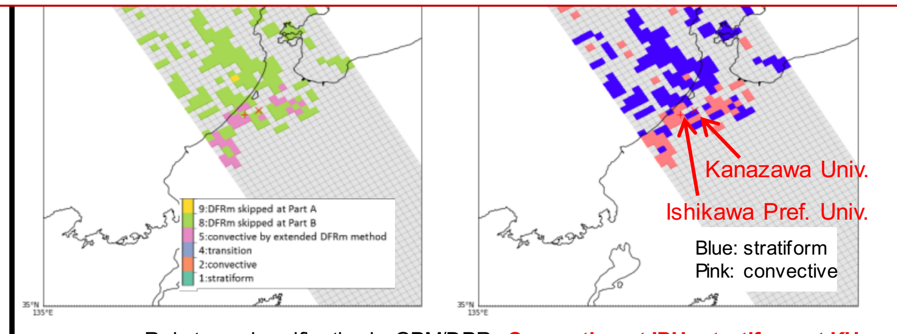
Ground validation of winter snow cloud type classification by G-PIMMS – GPM/DPR match-up case on January 25, 2017

by Profi. Suzuki (Yamaguchi Univ.)

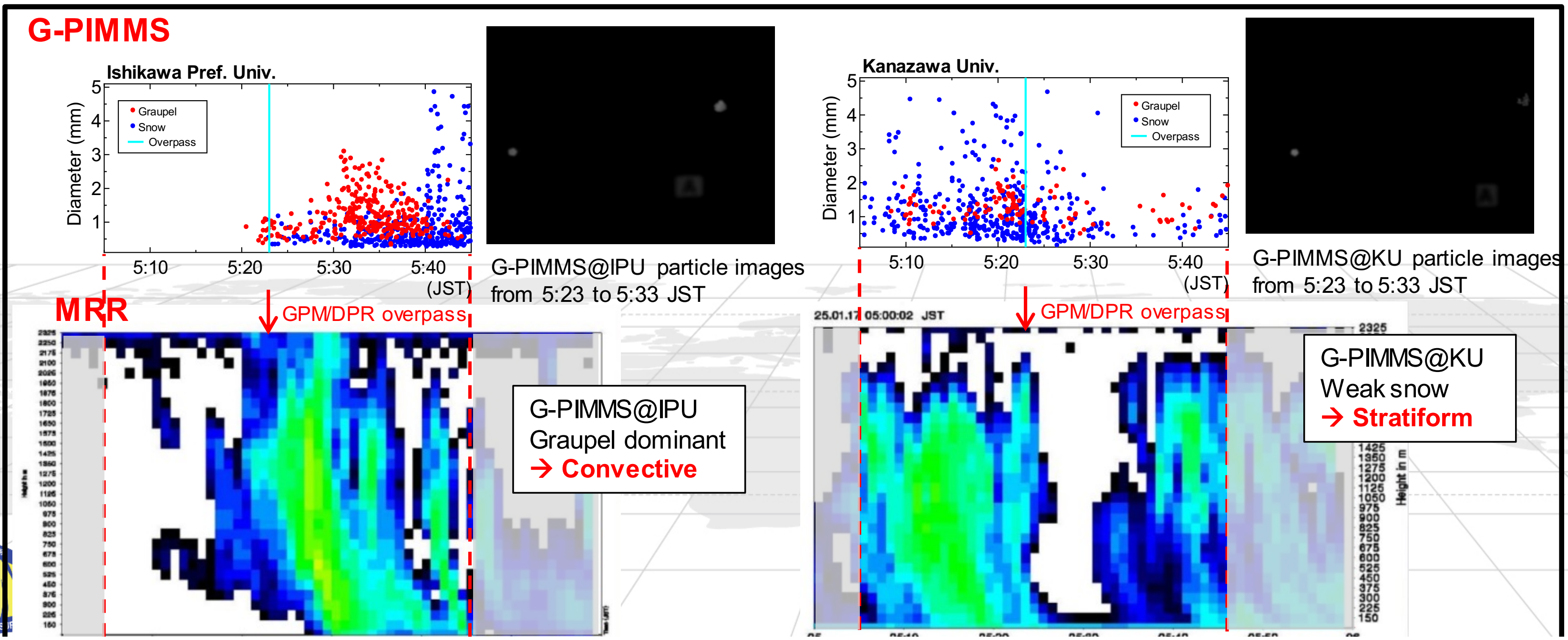
G-PIMMS directly measures the phase conditions of precipitation particles. Utilizing G-PIMMS match-up cases at Ishikawa and at Kanazawa, snow cloud type classifications (conv/strat) of GPM/DPR were validated and consistent with observations.



JMA radar of snow clouds on 0520JST, Jan.25, 2017



Rain type classification by GPM/DPR. **Convective at IPU, stratiform at KU**



APPLICATIONS

Group characteristics of DPR-captured Precipitation Systems

by Prof. Hirose (Meijo Univ.)

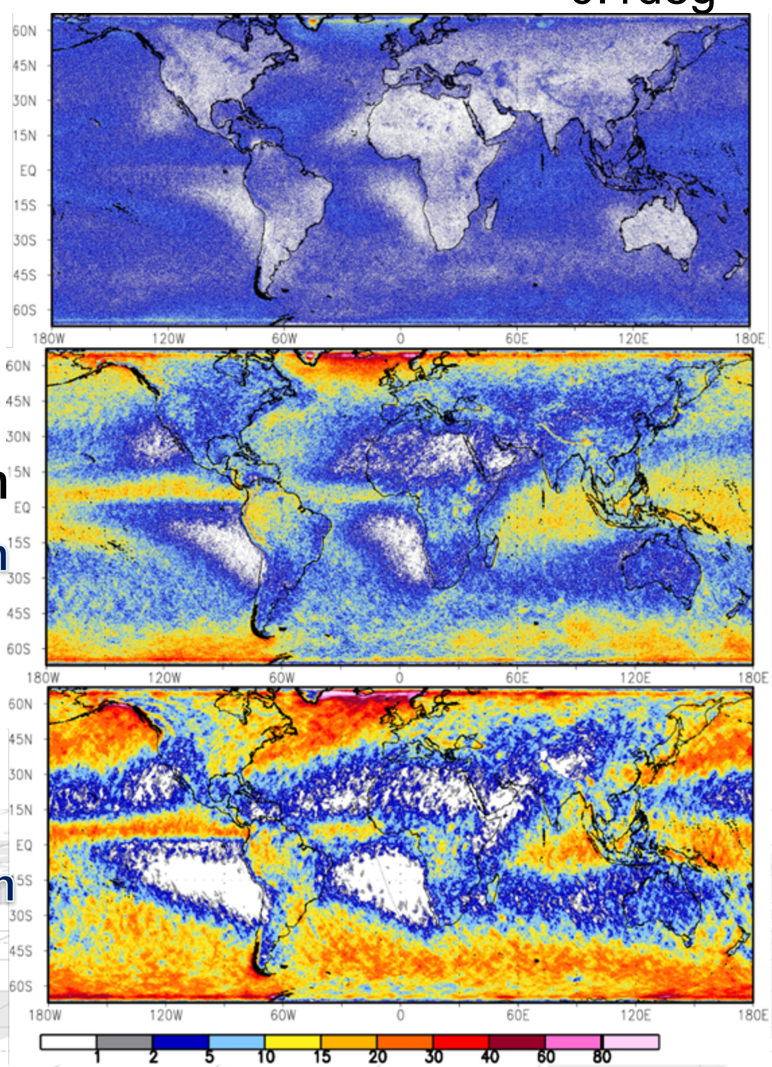
Number of rain samples

0.1deg

Small <10km

Medium 10-100km

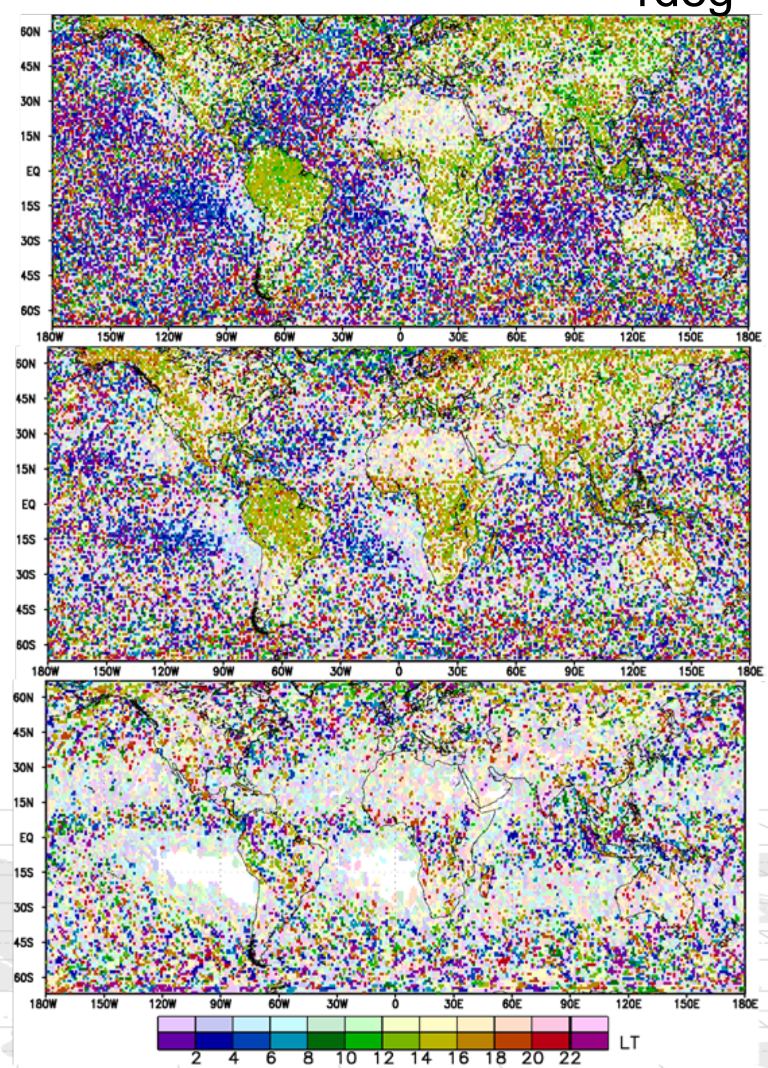
Large >100km



[FOVs/grid]

Time of max hourly rain

1deg



Dark-colored shading: rain within 1 hr of the time of max rain preserves positive anomalies.

KuPR 04A
2014/4-2016/3

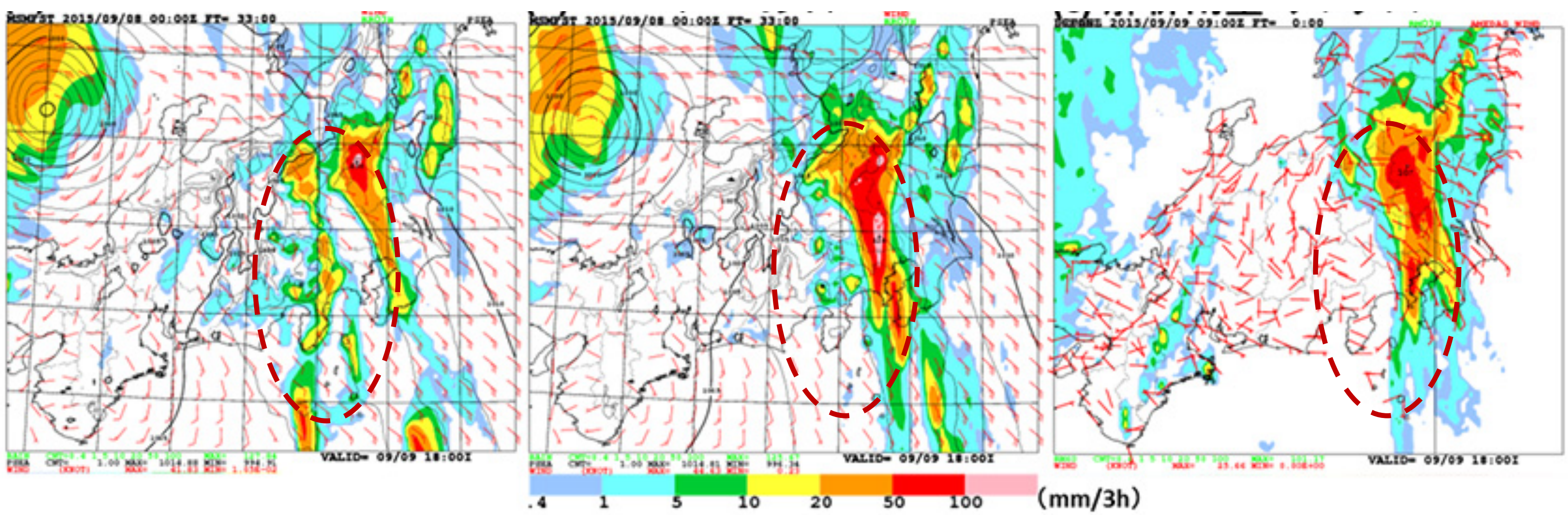
GPM/DPR Data Assimilation in the JMA NWP system

The Japan Meteorological Agency (JMA) started the DPR assimilation in the meso-NWP system on March 24 2016.
Word's first "operational" assimilation of spaceborne radar data in the NWP system of meteorological agencies!

a) 33-hour prediction without the DPR

b) 33-hour prediction with the DPR

c) Observation



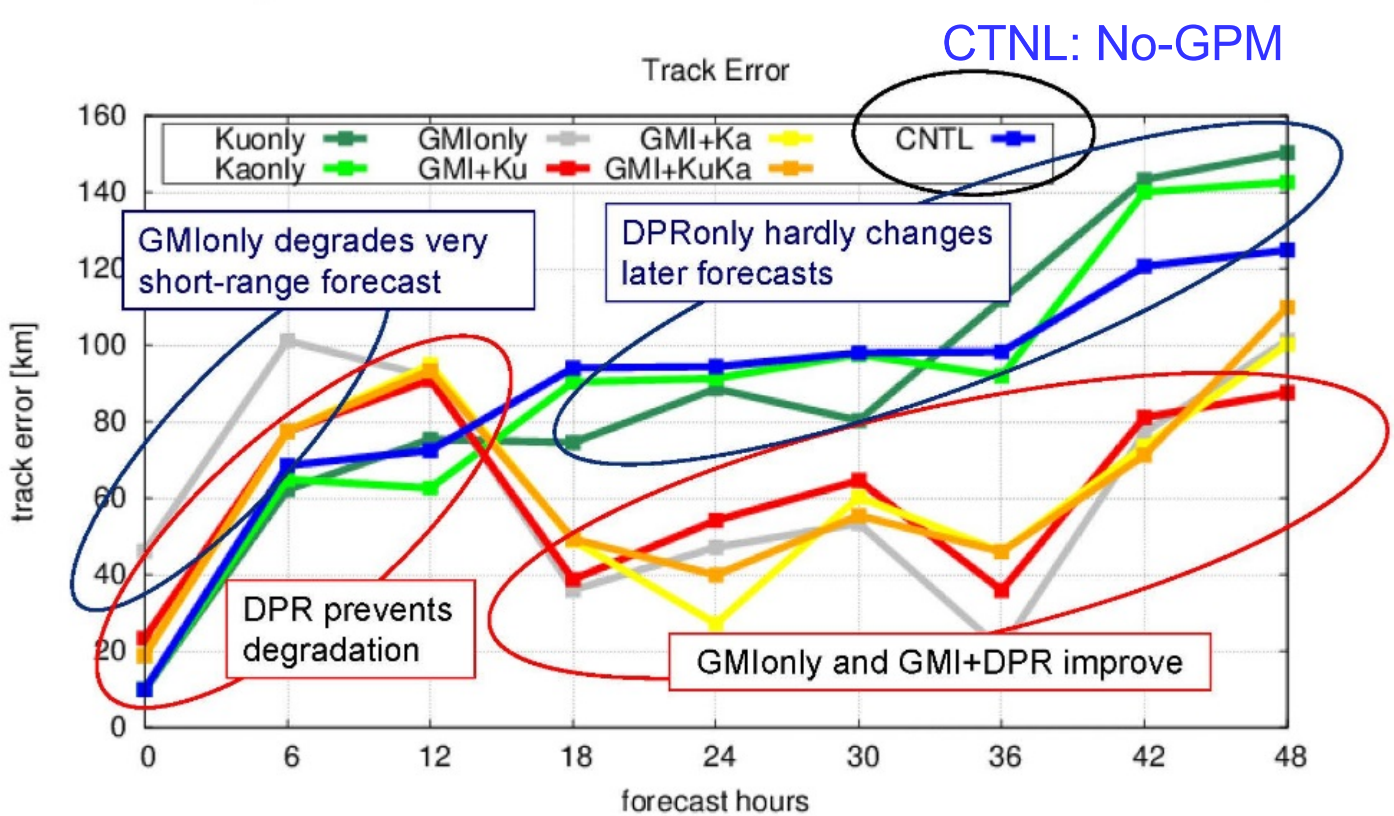
Provided by JMA

- **Example of Kanto-Tohoku Heavy Rainfall in 2015**
- **Improvements in water vapor analysis accuracy over the ocean**
- **Improvements in rainfall forecast accuracy**

Effect of GPM-Core Data in the NWP system

Forecast verification : Position error

- DPR assimilation yields small errors in the very short-range forecast
- DPR + GMI generates smallest errors overt the entire forecast range



Okamoto et al. (2016)
" Experimental assimilation of the GPM-Core DPR reflectivity profiles for Typhoon Halong"
Mon. Wea. Rev.

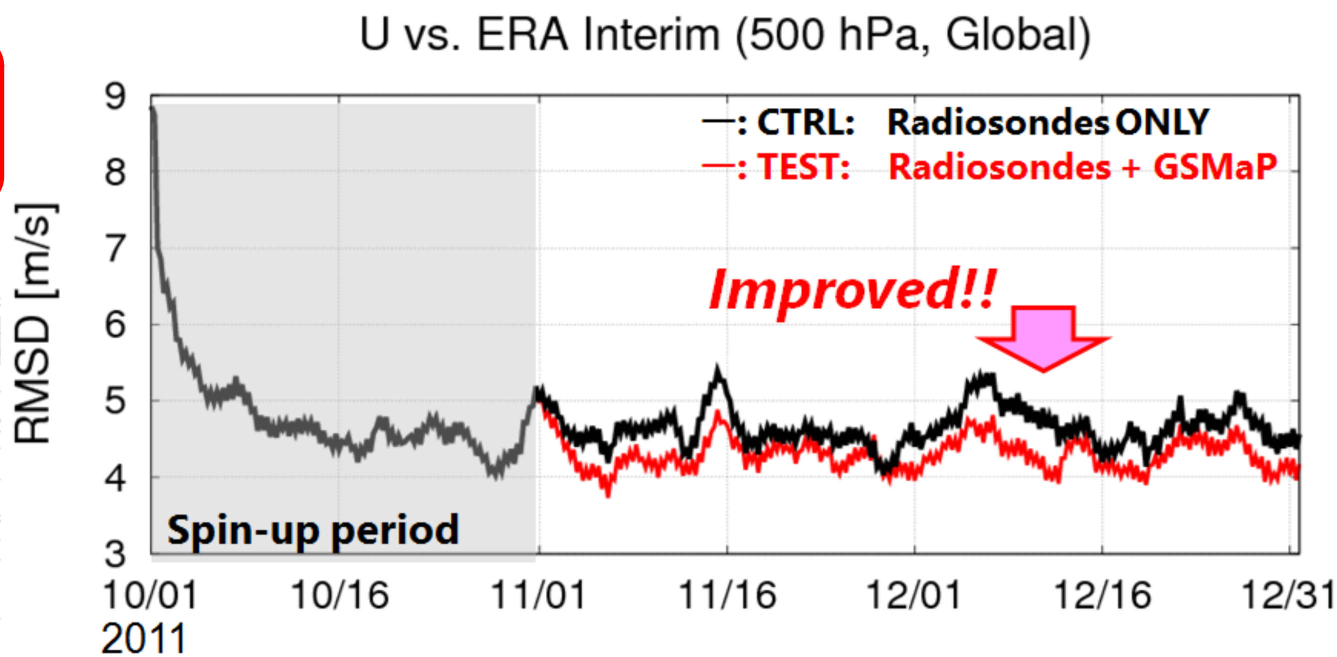
K. Okamoto, K. Aonashi, T. Kubota, T. Tashima, 2016: Experimental assimilation of the GPM-Core DPR reflectivity profiles for Typhoon Halong, *Mon. Wea. Rev.*, 144 (6), 2307-2326.

GPM/DPR Data Assimilation in RIKEN

PI: T. Miyoshi

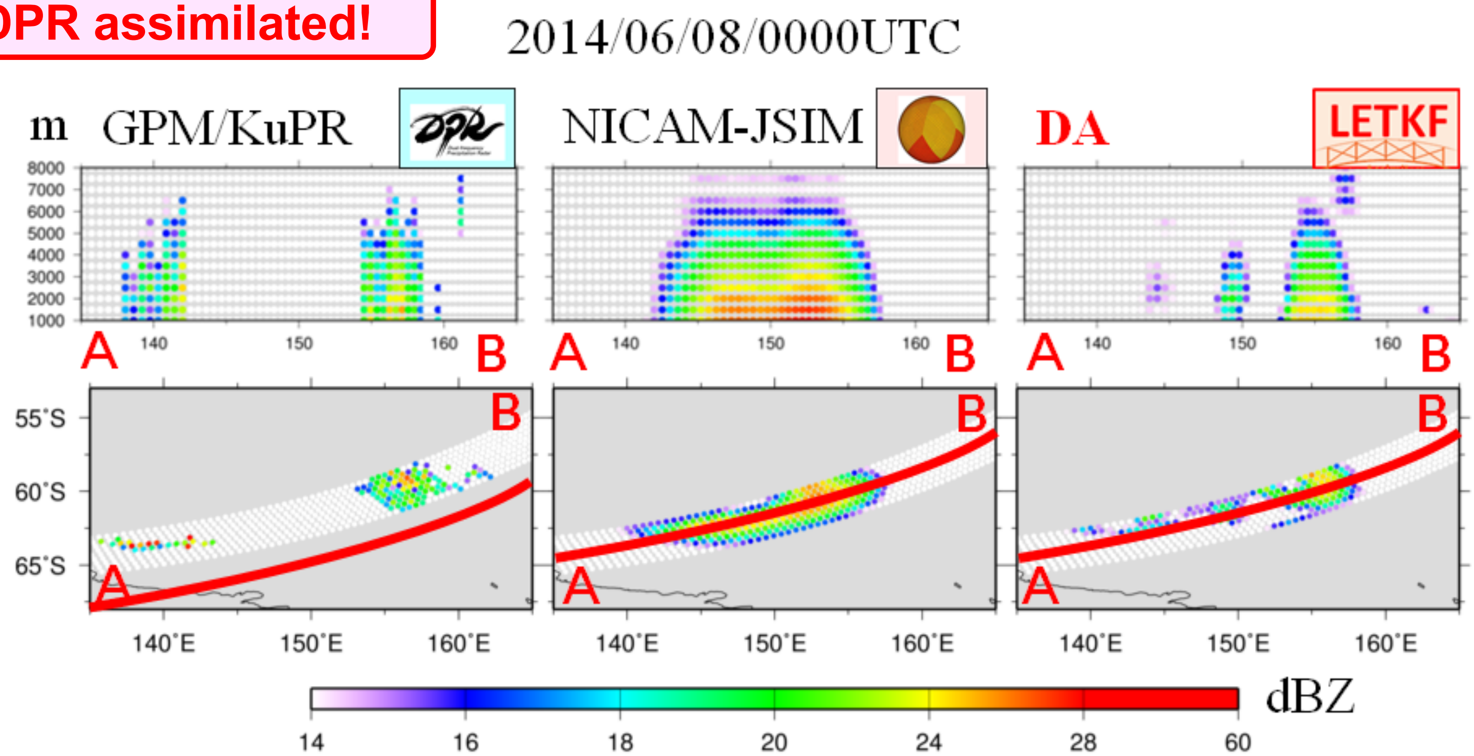
- **NICAM-LETKF upgraded**
  - AMSU assimilated (***Terasaki et al.***, under review)
  - GSMaP assimilated (***Kotsuki et al.*** 2017, JGR)
  - New framework (***Yashiro et al.*** 2016, GMD)
  - Inflation revised (***Kotsuki et al.*** 2017, QJRMS)
  - Theoretical study (***Terasaki et al.*** 2015, SOLA)
  - Model parameter estimation (***Kotsuki et al.***, in prep)
  - GPM/DPR compared (***Kotsuki et al.*** 2014, SOLA)
  - GPM/DPR assimilated (***Kotsuki et al.***, in prep)

GSMaP assimilated!



GPM/DPR Data Assimilation in RIKEN

GPM/DPR assimilated!



Real-time systems in RIKEN

➔ https://weather.riken.jp or
http://sharaku.eorc.jaxa.jp/GSMaP_RNC

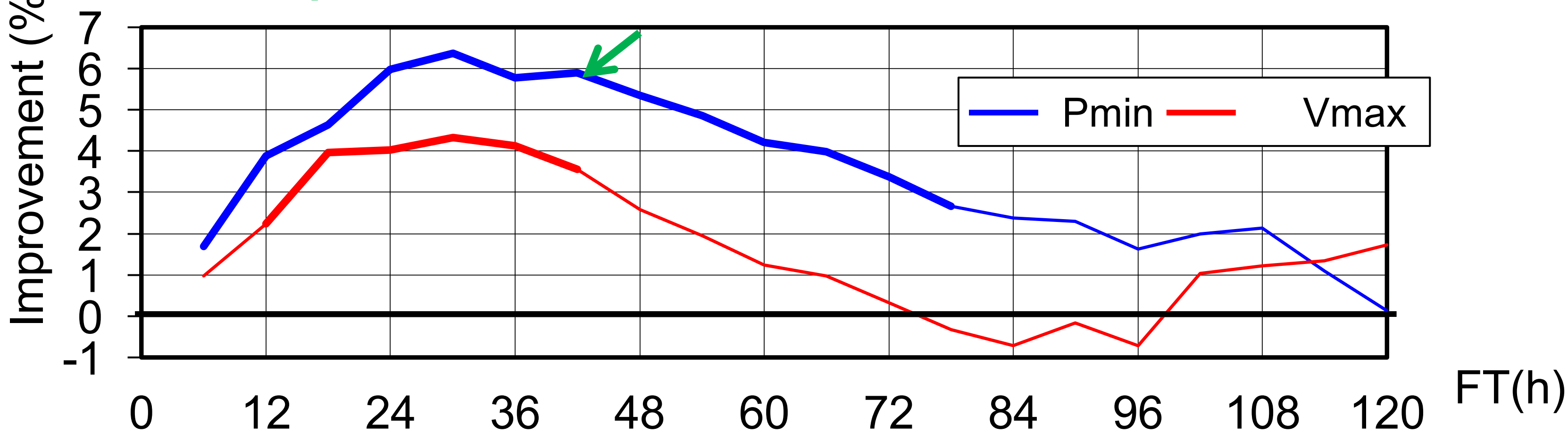
- **GSMaP RIKEN Nowcast (GSMaP_RNC)** (***Otsuka et al.*** 2016, WAF)
  - Real-time operation started from April 2017
- **Real-time NICAM-LETKF** (***Terasaki et al.*** 2015, SOLA), (***Terasaki et al.***)
  - Real-time system (***Kanemaru et al.***, in prep)

Improvement in a Statistical Hurricane Intensity Prediction Scheme (SHIPS) Using GSMaP Data

Axisymmetricity, horizontal size, rainfall max range, are obtained from GSMaP

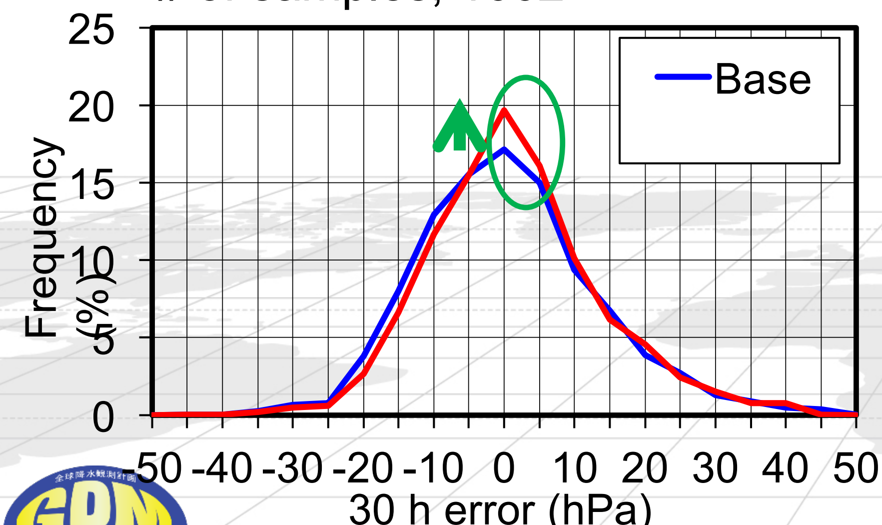
A 2-6% improvement for Pmin forecast

Shimada et al. 2017, MWR

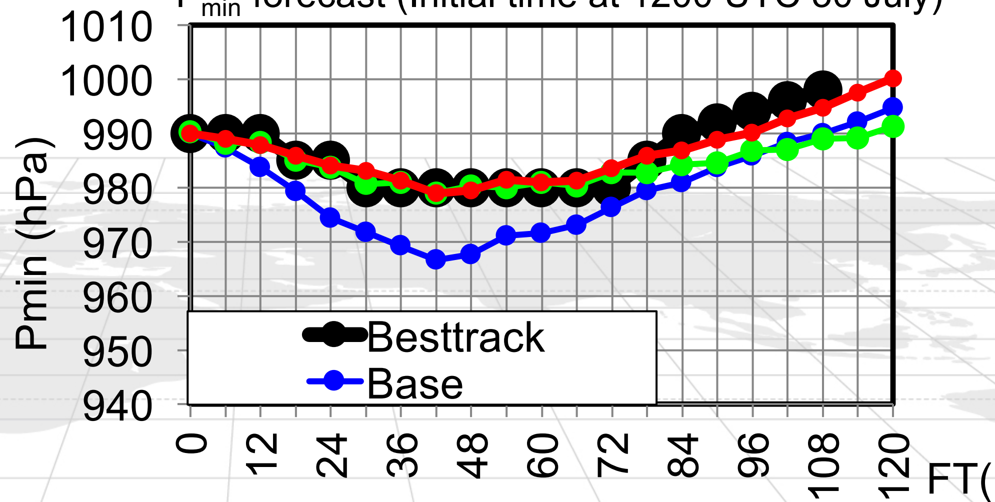


An excellent case (Typhoon Nakri 2014)

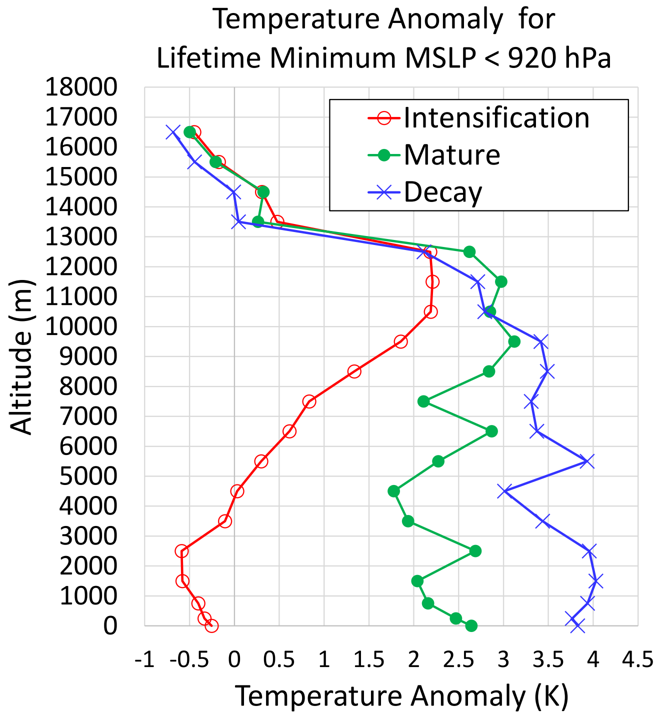
# of samples; 1662

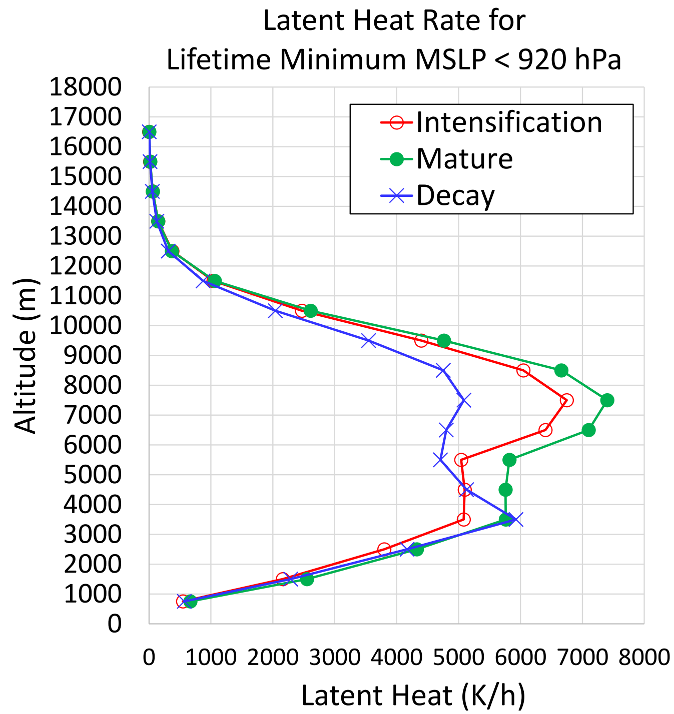


P_{min} forecast (Initial time at 1200 UTC 30 July)



Study to evaluate contribution of the latent heating to typhoon warm core formation (by Dr. Oyama, JMA.MRI)





Utilized TRMM SLH to evaluate the TC structure

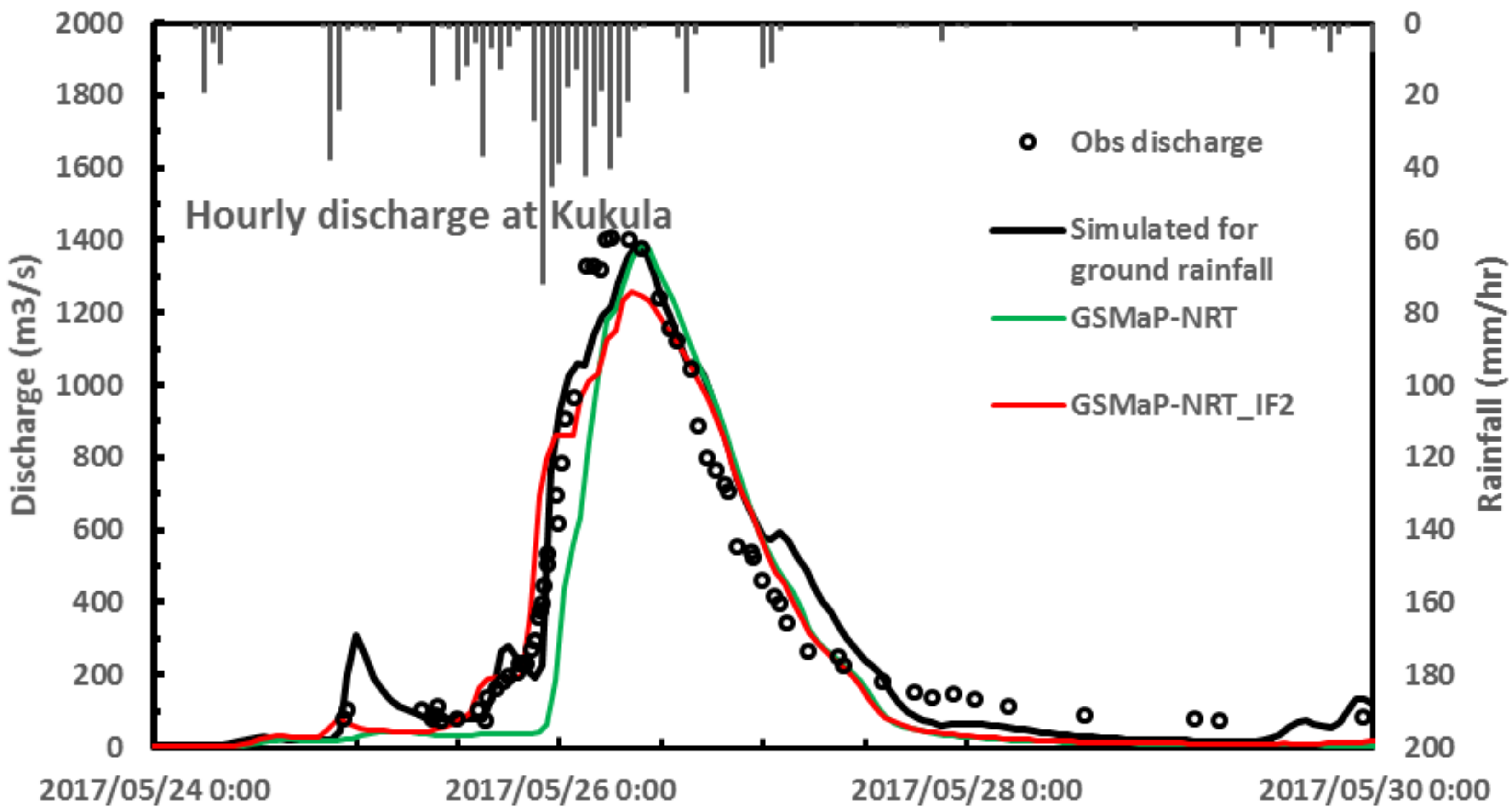
Highlights:

- This study evaluated the temperature anomaly maximum of tropical cyclone (TC) warm core obtained from 55-GHz band observations of AMSU-A/NOAA and latent heat rate (radius<150 km) from JAXA TRMM/PR L2H25 (Ver.7) for 339 TCs occurring during 2000-2014.
- The altitude of warm core temperature anomaly peak for TC intensification and mature phases tended to be higher than that for TC decay phase (Left figure).
- The latent heat release for TC intensification and mature phases tended to occur in the mid troposphere while occurring in the lower troposphere for TC decay phase (Right figure)
- These results suggest that the development of TC warm core was essentially caused by the release of latent heat via the deep convection near the TC center.

Hydrological river discharge simulation in Sri Lanka

by Mohamed Rasmy Abdul Wahid (ICHARM)

Discharge Simulation at Kukula hydro-power Station



Discharge simulation performs well with GSMaP-NRT_IF2 at the early stage and with GSMaP-NRT at the peak

Summary of GPM Science Status in JAXA

- New algorithm is developed for GPM DPR precip. estimates, utilizing Dual frequency observations.
- New flags are added for HeavyIce-P, Anvil-P, and surface snow.
- Spectral Latent Heating algorithm is extended to mid-latitudes.
- A new version of GPM-GSMaP was released on Jan. 2017, with improvements in snowfall estimates.
- Precipitation estimates over Japan and the US were validated and satisfied the success criteria.
- Direct measurements of k & Ze with dual Ka-radar system validated the theoretical model.
- JMA started the DPR assimilation in the operational meso-NWP system from March 2016.
- Various assimilations of DPR, GMI, and GSMaP are successfully performed and improved the forecasts.
- GSMaP is widely utilized in flood prediction, discharge simulations, and land slide warnings in Asian countries.

Dual-frequency algorithm

- **Main stream is same as KuPR algorithm,**

  KuPR's Z_m → KuPR's Z_e → DSD & precipitation rate

- **But, several dual-frequency methods are applied**
  - **PIA(KuPR) is estimated by Dual-frequency SRT (DSRT)**
    - **δPIA≡PIA(KaPR)－PIA(KuPR) is estimated by DSRT**
    - **PIA(KuPR)=δPIA/(p+1) where p=PIA(KaPR)/PIA(KuPR)**

    (Meneghini et al. 2012, IEEE TGRS)
  - **k-Z_e relation is initially set according to Dual-frequency type classification (DFR_m method)**

    (Le and Chandra 2013, IEEE TGRS)
    - **DFR_m=dBZ_m(KuPR)－dBZ_m(KaPR)**
  - **k-Z_e relation is modified by HB-DFR-SRT method by means of KaPR's Z_m in V03**

    (Seto et al. 2013, 2015)
  - **R-D_m relation is used in V04 & V05.**

Main topics of GPM DPR L2 rain type classification (CSF) module V5

PI: Jun Awaka (Tokai University)

1) Introduced the following new flags:

- **flagHeavyIcePrecip** (proposed by Dr. Iguchi.)
  - Which examines Z at higher altitude where the temperature is below -10C.
  - The flag consists of Ku-band decision, Ka-band decision, and DFRm decision, where DFRm means the measured dual frequency ratio of Z factors.
- **flagAnvil** (as requested by Dr. Hamada.)
- **Surface snowfall & snow index** developed by Drs. Chandra and Le. (Implemented as Experimental.)

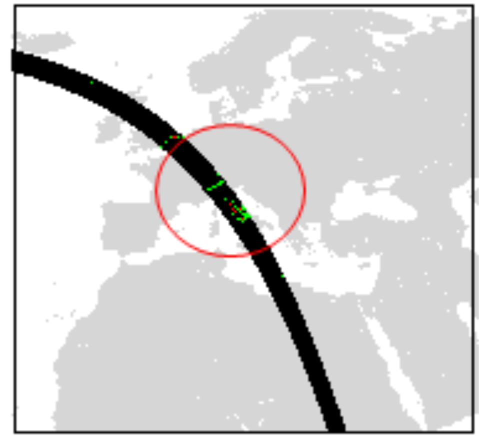
2) Added a code for detecting low temperature convection (e.g. high latitude winter convection) . The code examines the DFRm at and around the storm top and also uses the information about flagHeavyIcePrecip.

3) zFactorCorrected (from SLV) is used for convective decision in the single frequency

- V-method because each single frequency L2 algorithm has a loop structure.

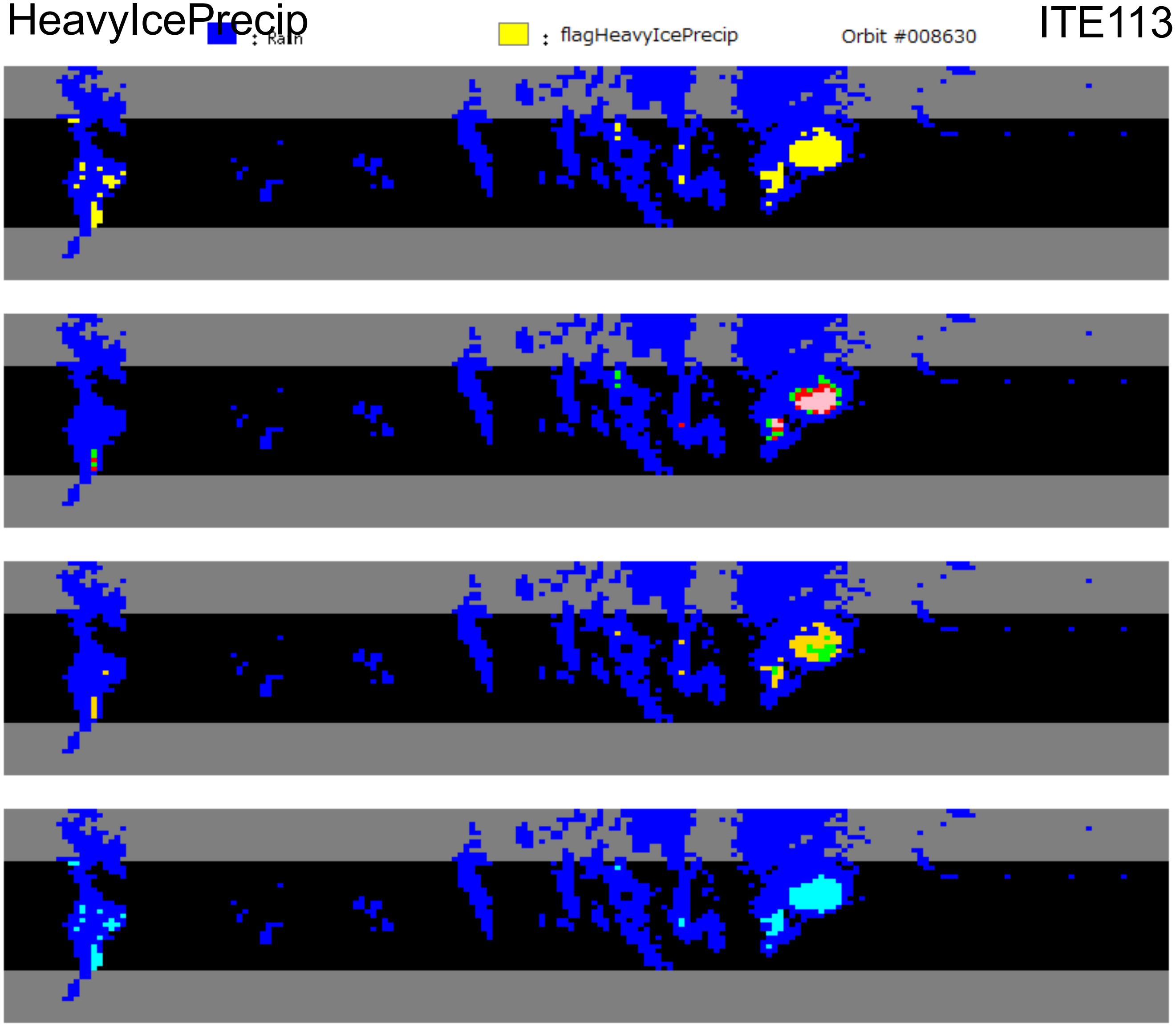
DPR flags for solid precipitation particles:
flagHeavyIcePrecip

2015/09/05
Orbit #008630



Only data above the -10 deg C are used to detect HeavyIcePrecip

ITE113



flagHeavyIcePrecip

=

Ku decision

Z(ku) > 45 dBZ
45 >= Z(ku) > 40 dBZ
40 >= Z(ku) > 35 dBZ

+

Ka decision

Z(ka) > 40 dBZ
40 >= Z(ka) > 35 dBZ
35 >= Z(ka) > 30 dBZ

+

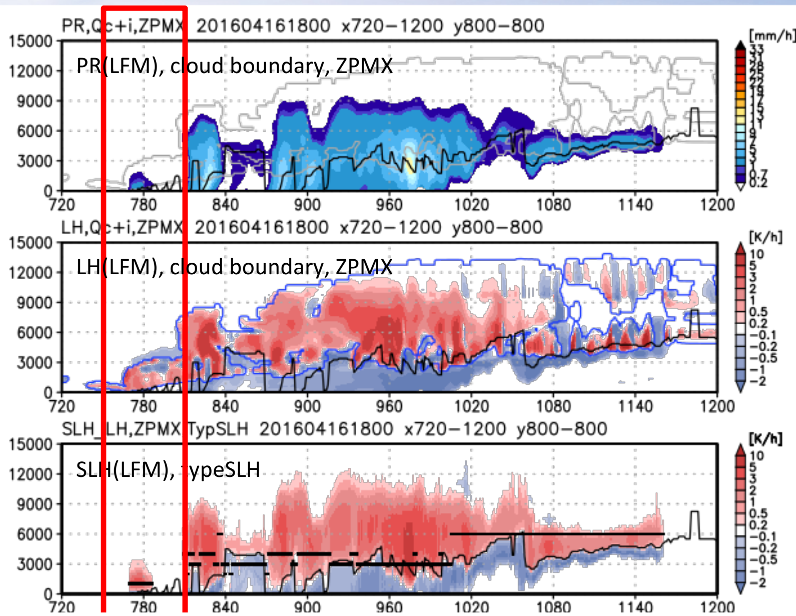
DFRm decision

Z(ku) > 27 dBZ and
DFRm > 7 dB

Precip

Simulated LH

Retrieved LH



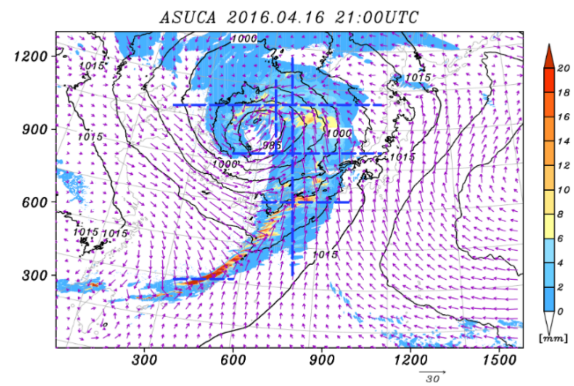
Consistency Check

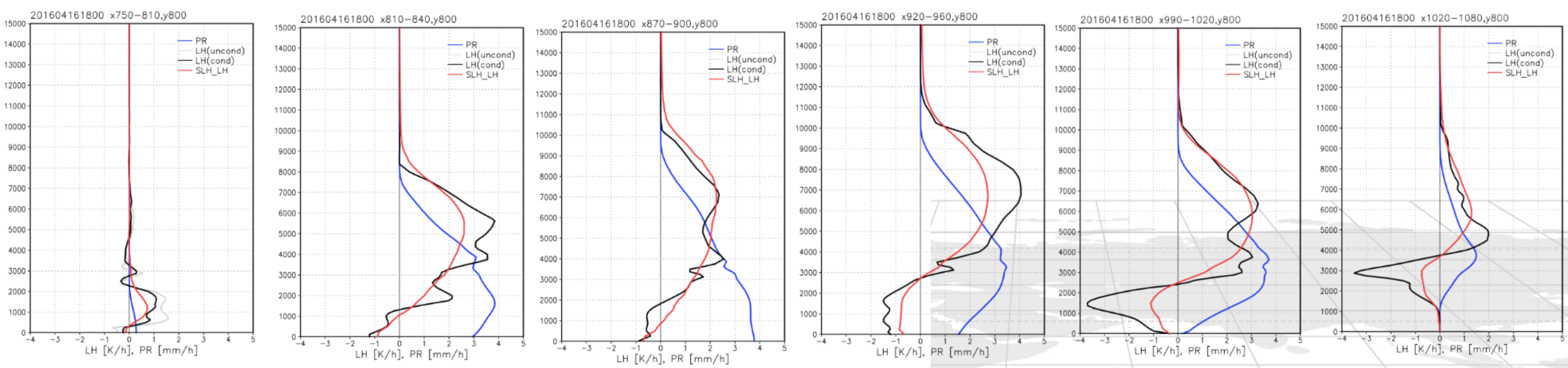
Average in x-direction

-- Precipitation

-- Simulated LH (con

-- Retrieved LH





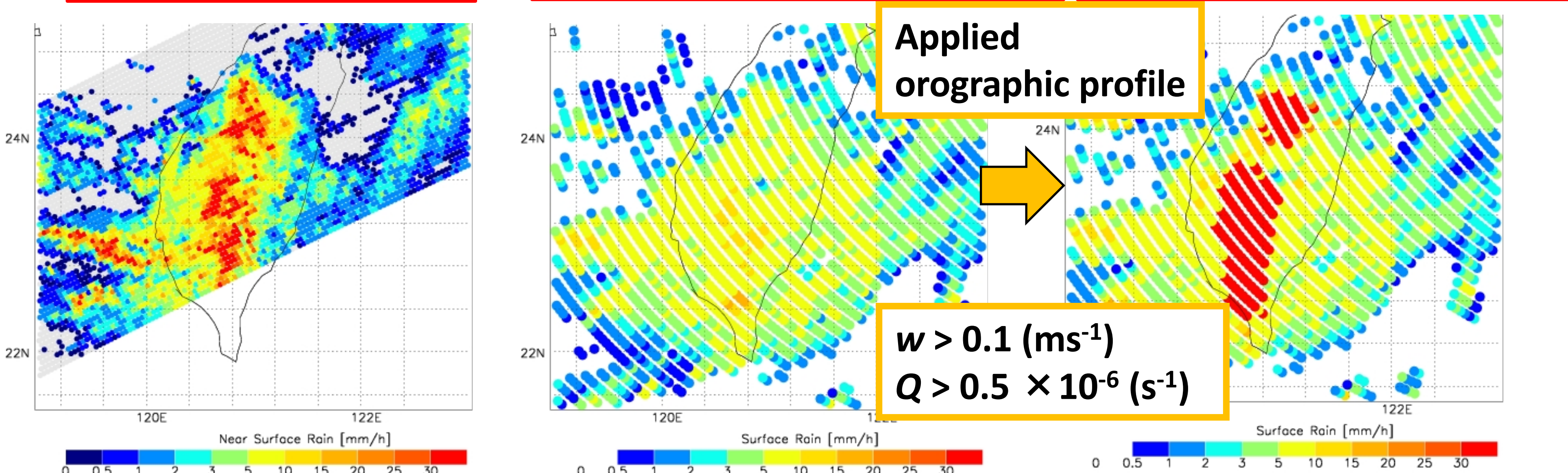
*black : conditional mean

Typhoon Morakot (2009) over Taiwan

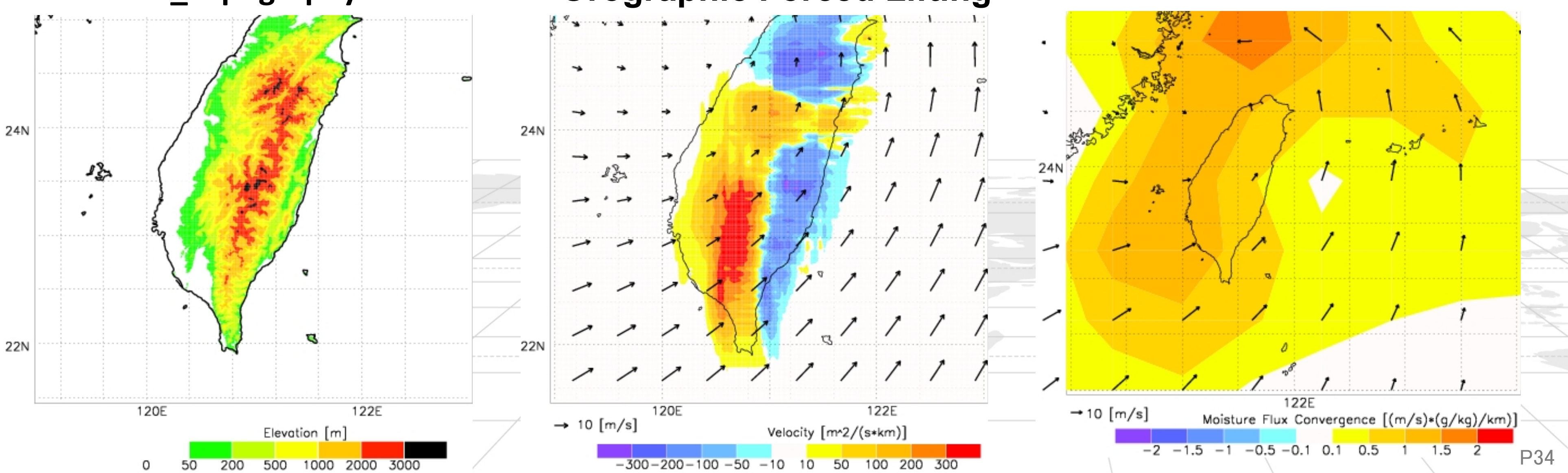
→ Integrated into the latest algorithm (Version 6)

Taniguchi et al. (2013, JHM)

PR _ Near Surface Rain | GSMaP_TMI_Surface Rain (orig.) | GSMaP_TMI _Surface Rain



SRTM30_Topography | Orographic Forced Lifting | Convergence of Surface Moisture Flux



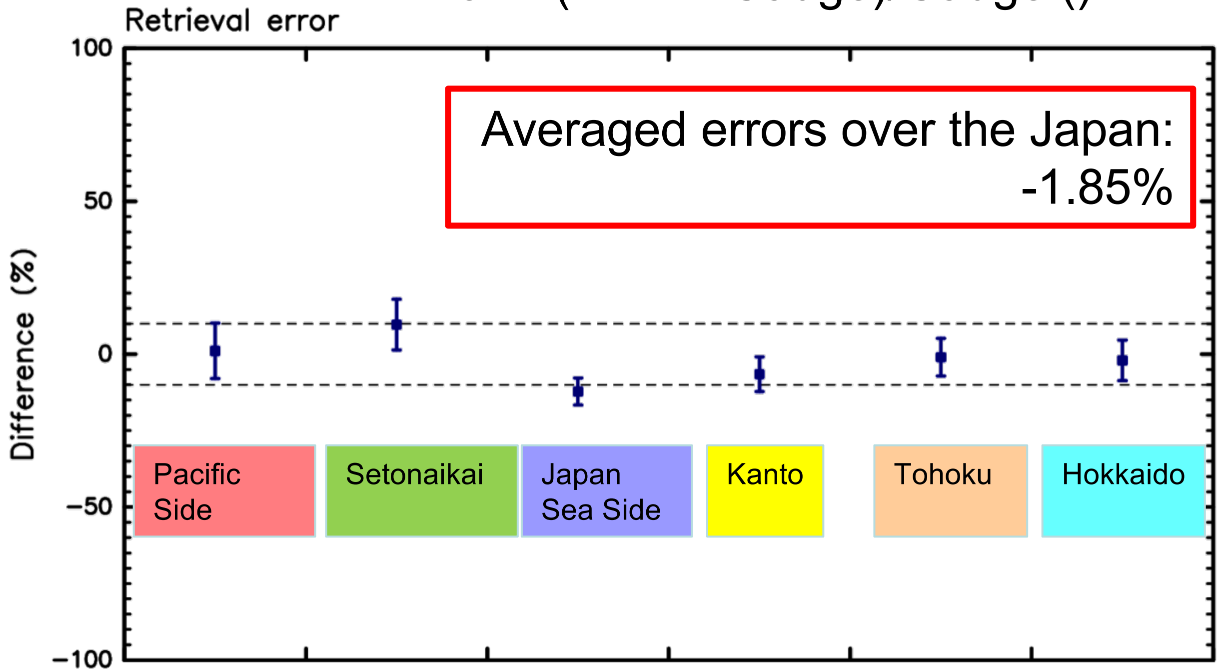
GPM-GSMaP V04 (Algorithm version 7)

- **The GSMaP products was updated to Product version 04 (V04A)/Algorithm version 7 on 17th Jan., 2017.**
  - **The data from March 2014 will be reprocessed by the end of Mar. 2017. After that, the data from Mar. 2000 will be reprocessed.**
- **There are following improvements in V04 from V03.**
  1. **Improvement of GSMaP algorithm using GPM/DPR observations as database (DB)**
  2. **Improvement of the algorithm over the high latitudes by implementation of snowfall estimation method and NOAA multisensor snow/ice cover maps**
  3. **Improvement of gauge-correction method in both near-real-time and standard products**
  4. **Improvement of orographic rain correction method**
  5. **Improvement of weak rain detection over the ocean by considering cloud liquid water**

Validation

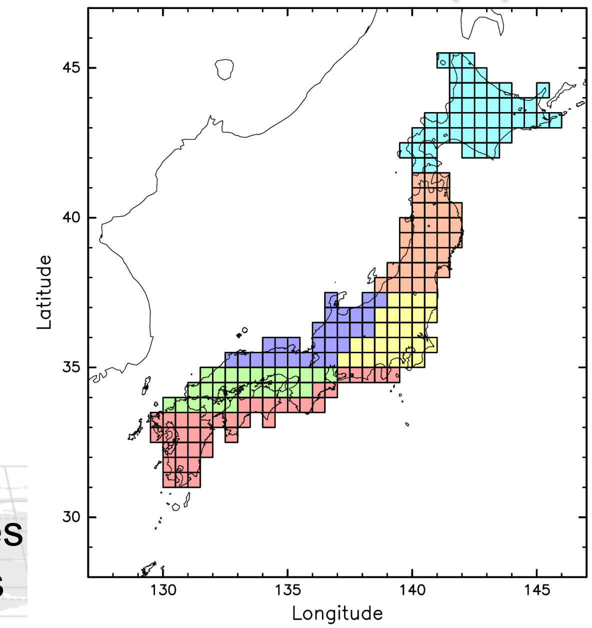
Comparisons of DPR rain estimates with JMA AMeDAS rain gauge data

Error = (DPR – Gauge)/Gauge ()



6 areas

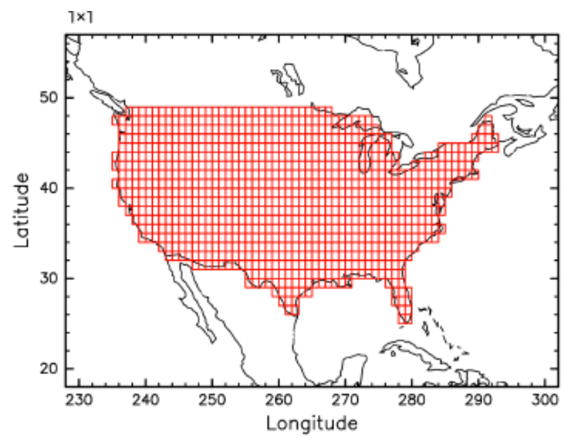
1. Hokkaido (No. of boxes: 45)
2. Tohoku (34)
3. Kanto (27)
4. Sea of Japan side (27)
5. Inland Sea area (27)
6. Pacific Ocean side (39)



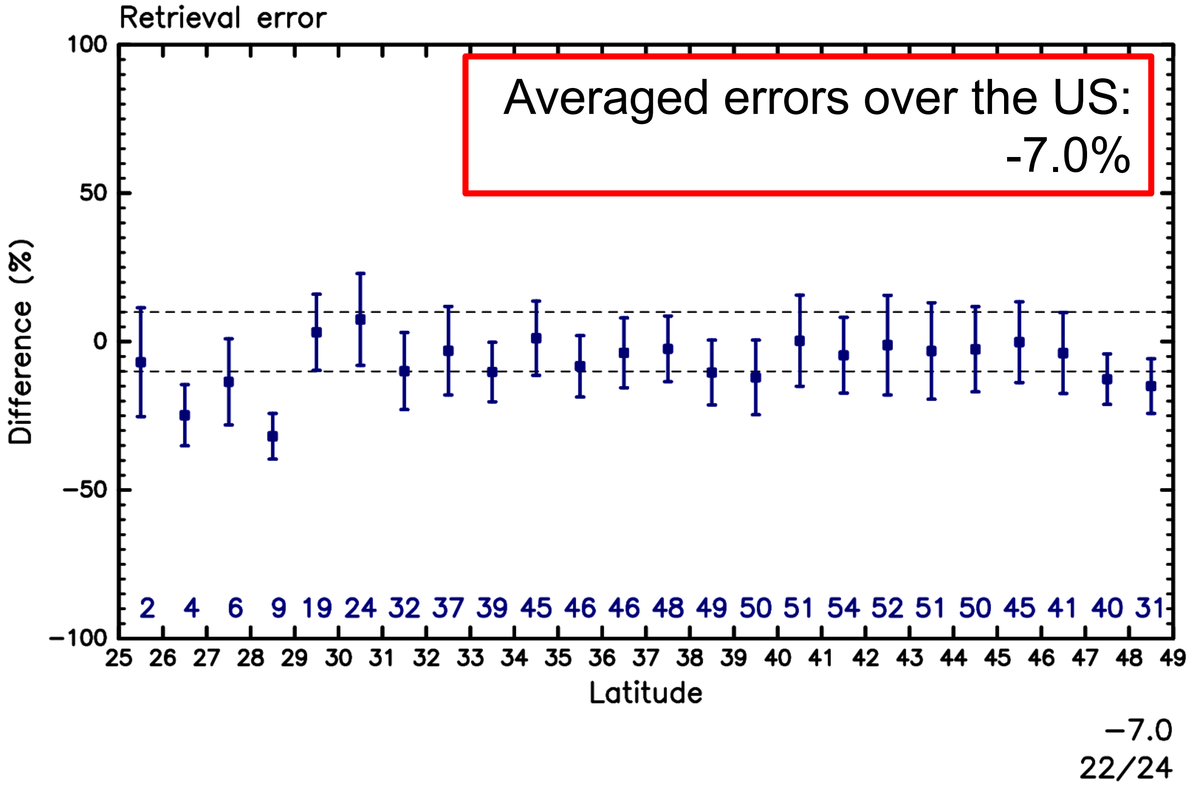
- Two years of data from June 2014 to May 2016
- AMeDAS data at overpasses only
- Gauge data are 10 min data immediately after the overpasses
- Rain total is estimated at each 0.5 × 0.5 deg. box, and means and standard deviations of 6 colored areas are calculated.
- To exclude snow fall data, if the surface temperature is below 6 degrees, data in that box are not used.

DPR(MS) (V05) and US MRMS: Zonal rain comparison

- US Multi-Radar Multi-Sensor (MRMS) DatasetMRMS (provided by NASA GV team)
- June 2014 – Mar. 2016 without winter season (Dec. Jan. Feb)
  - DPR overpass time only



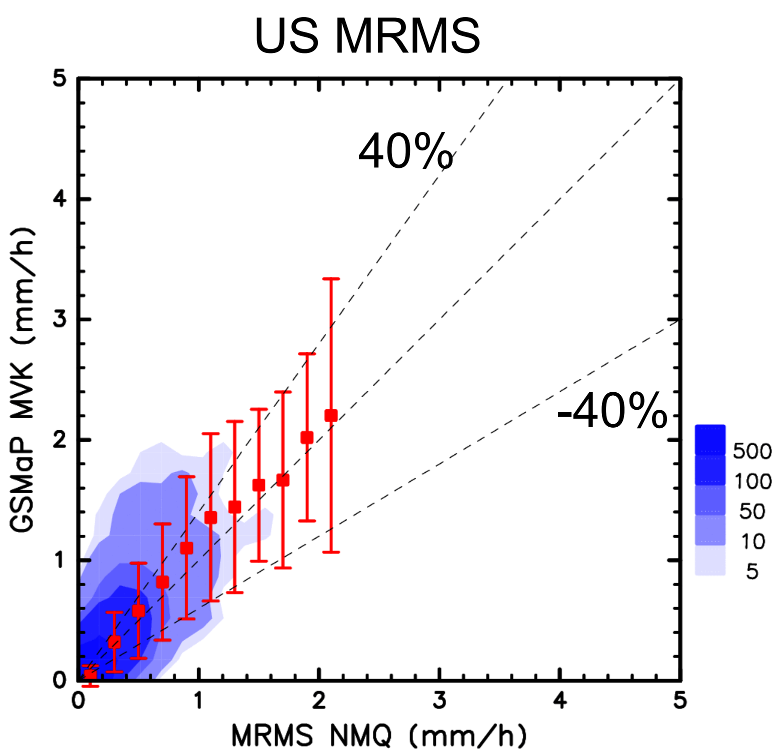
$\frac{\text{DPR - MRMS}}{\text{MRMS}}$

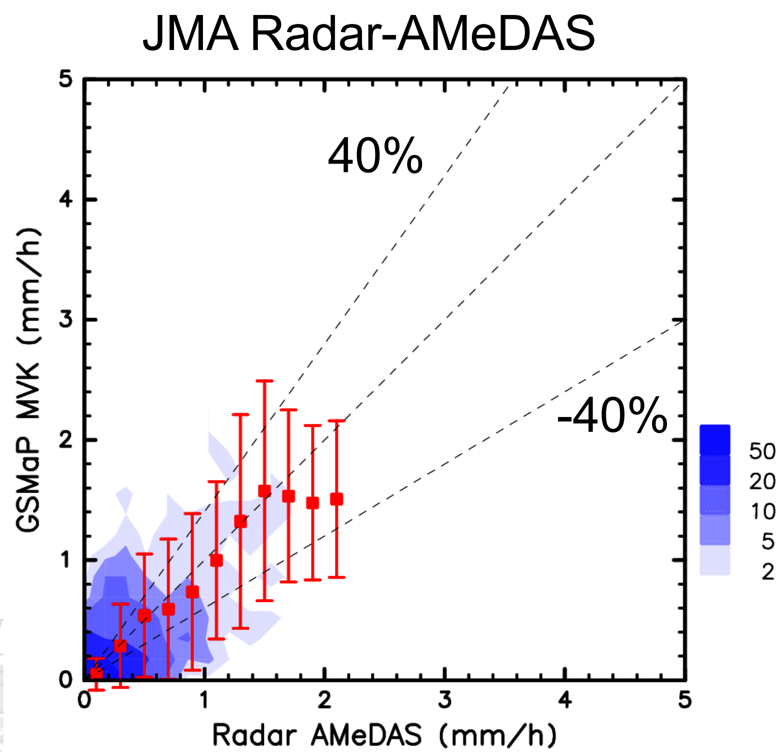


Error = (DPR – MRMS) /MRMS (%)

Validation results of the GSMaP

- **Validation results of the GSMaP v6 standard product (GSMaP_MVK, no-gauge-adjustment) are shown using US MRMS and the JMA Radar-AMeDAS (gauge-corrected radar) data during Jun.-Aug. 2015 with 1.5x1.5 lat/lon, daily grids.**





The GSMaP_MVK v6 product well-corresponded to the ground instruments over the Japan and US, except for higher rain rates over the Japan.

Nagaoka Experiment Summary

- Measured k-Z_e relations of snow were divided into those of wet snow, dry snow and graupel.
- Existences of wet snow, dry snow and graupel were confirmed by velocity-size distributions from 2DVD data.

	characteristics of k-Z_e relations	surface temperature
wet snow	• k-Z_e relations scatter. • Larger k values than that of rain appear.	more than 0 ºC
dry snow	• k is constant even when Z_e increase.	less than 0 ºC
graupel	• k increases with Z_e	less than 0 ºC

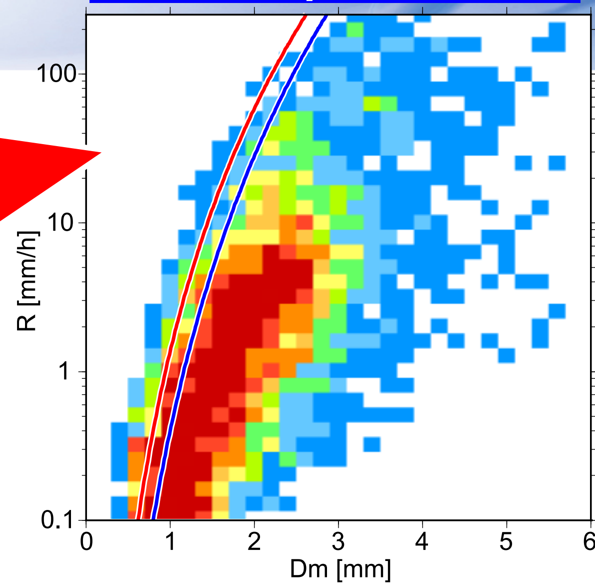
(Nishikawa et al., TGRS, 2015)

Obtained raindrop size distribution, as in R-Dm frequency distribution

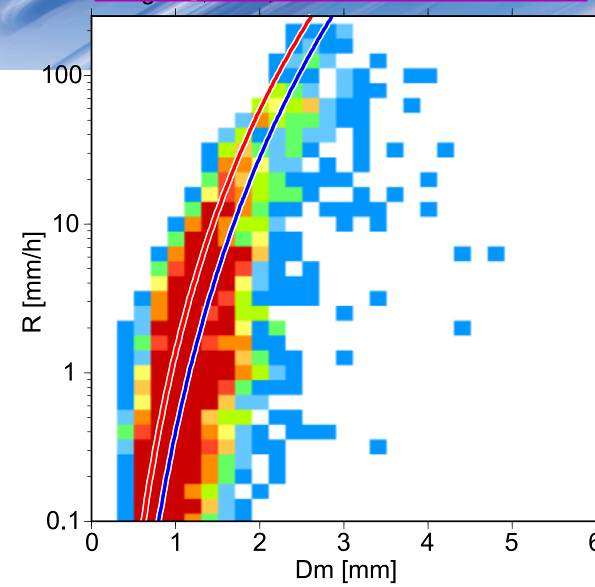
by Dr. Katsumata (JAMSTEC)

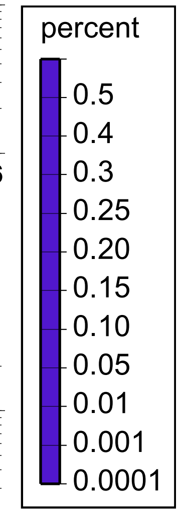
Only one outlier from Kozu et al. (2009) DSD, on the rain over coastal ocean near Sumatra west coast

R/V Mirai, pre-YMC

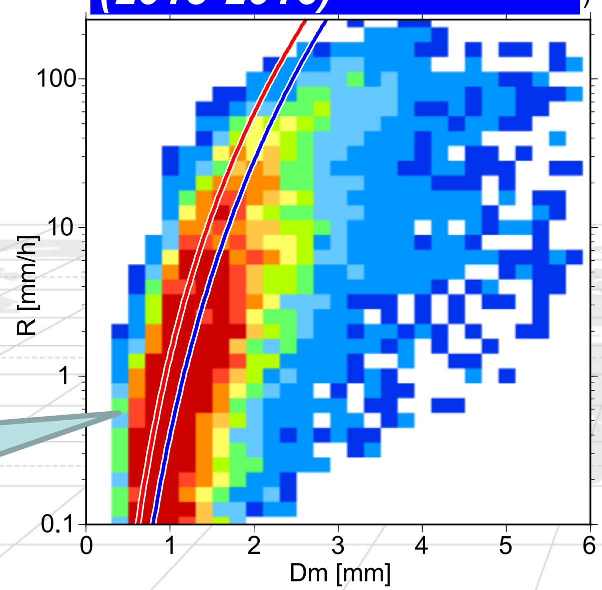


Bengkulu, pre-YMC



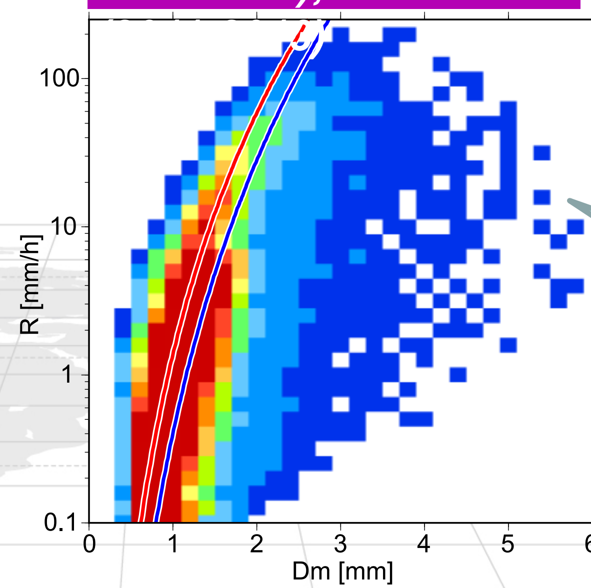


R/V Mirai, Open Ocean (2013-2016)



*obtained in PMM 7th / 8th RA

Laos (=inland Indochina),



*obtained in PMM 6thRA (PI: Dr. Satomura @ Kyoto U.)

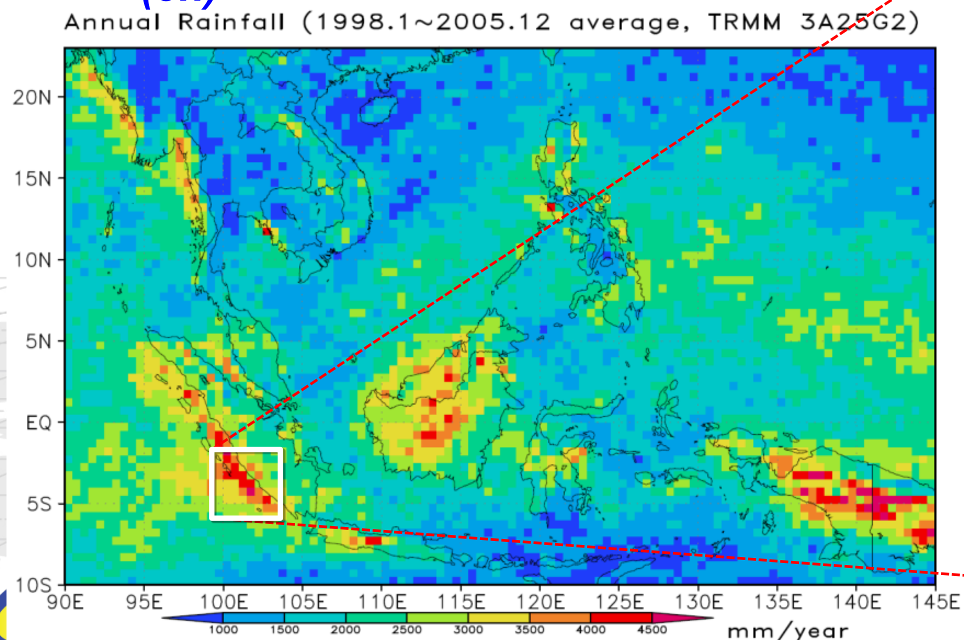
Special Observation "Pre-YMC" in Nov.-Dec. 2015 (by Dr. Katsumata, JAMSTEC

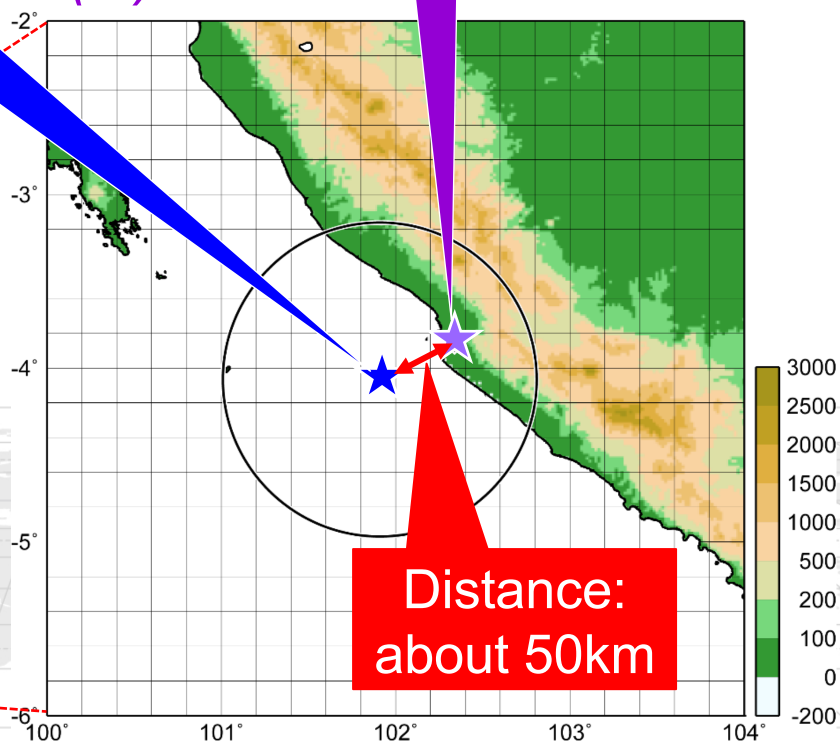
Ocean Site: *R/V Mirai*

C-band radar Surface Met. Disdrometers Ka-band VP radar Radiosonde (3h)	***"SeaSnake" TSG (intake@5m) CTD (6-300m) etc.***

Land Site: *BMKG Bengkulu*

Surface Met. Disdrometers Radiosonde (3h)	***Videosonde etc.***



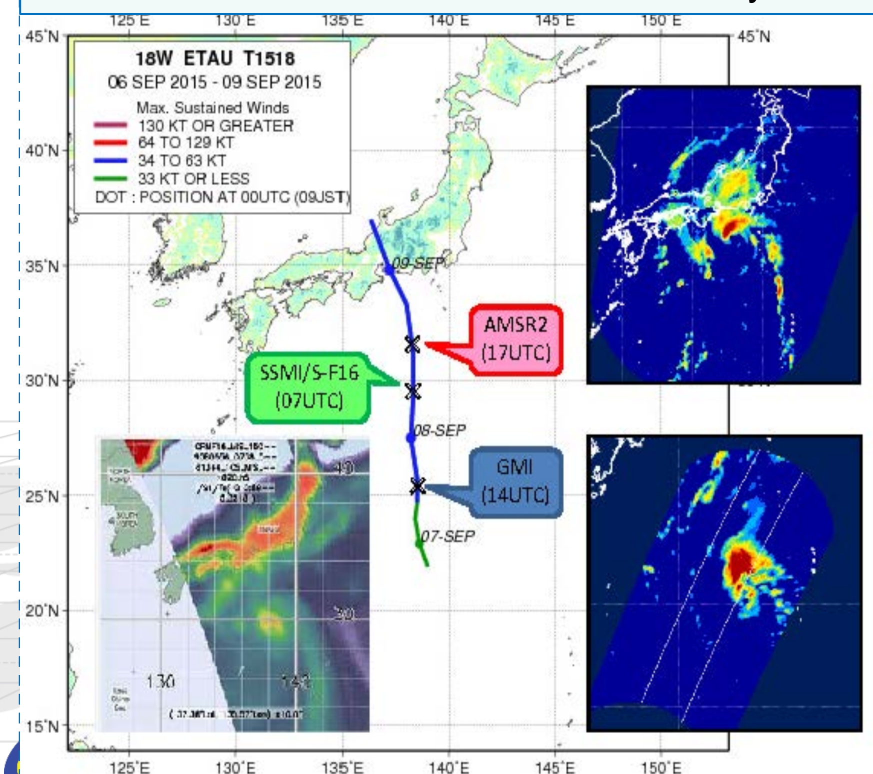


Applications

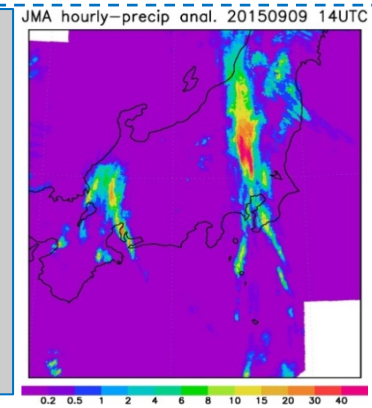
Ensemble-based variational assimilation of GMI, AMSR2, and SSMIS TBs for Typhoon Etau (T1518)

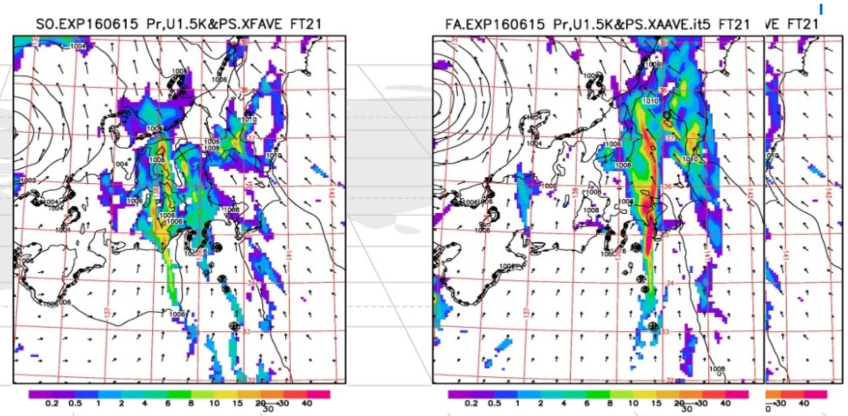
Dr. Aonashi (JMA/MRI) has constructed a forecast analysis (FA) system of an EnVAR scheme for a CRM. Assimilation of GMI, AMSR2, and SSMIS TBs using this system for Typhoon Etau gave large forecast improvement of precipitation bands over Kanto plain.

The track of Typhoon Etau (T1518) and MWI TBs assimilated with the EnVAR FA system



Hourly precip for 14UTC 9th Sep. 2015 (mm)
(up right) JMA Radar-gauge analysis
(down left) CRM 21h forecast without MWI assimilation
(down right) CRM 21h forecast with MWI assimilation





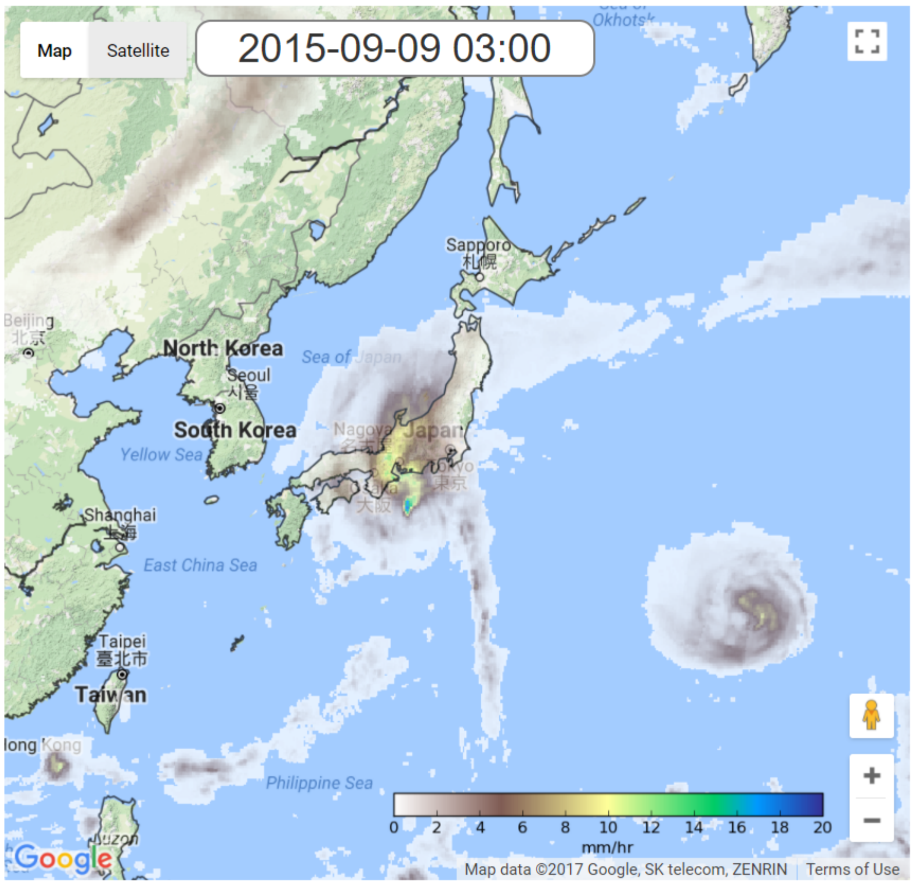
Flood Monitoring & Analysis

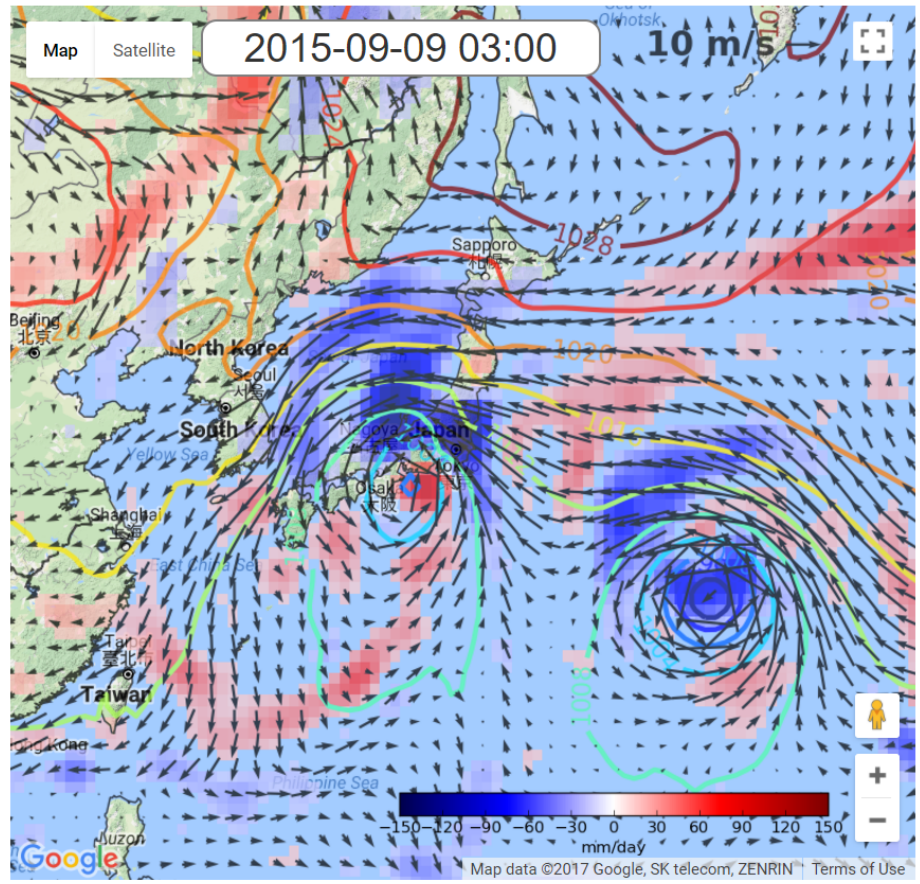
by Prof. Kim (Univ. Tokyo)

H27.09 KANTO/TOHOKU HEAVY RAIN (a.k.a. KINUGAWA KOUZUI)

GSMaP Precipitation (shade:left), JRA55 Column Integrated Water Vapor Divergence (shade:right), JRA55 Wind@900mb (vector:right), JRA Mean Sea Level Pressure (contour:right)

Rate: 1000ms Opacity: 70%

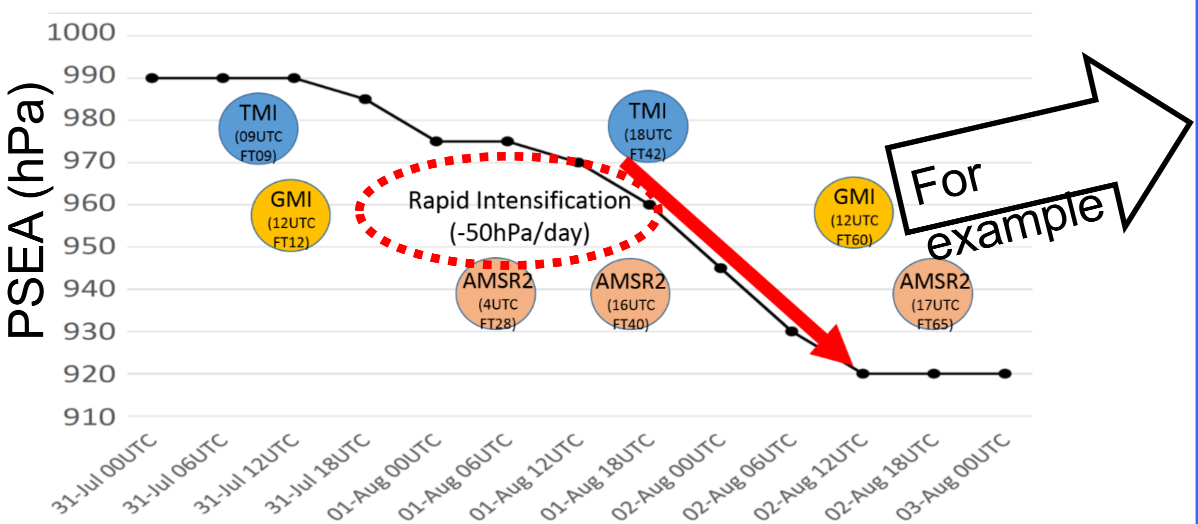




http://hydro.iis.u-tokyo.ac.jp/~hjkim/FLOOD.H27KT/app/

Evaluation of Tropical Cyclones Simulated in NWP Models by Dr. Yamaguchi (JMA/MRI)

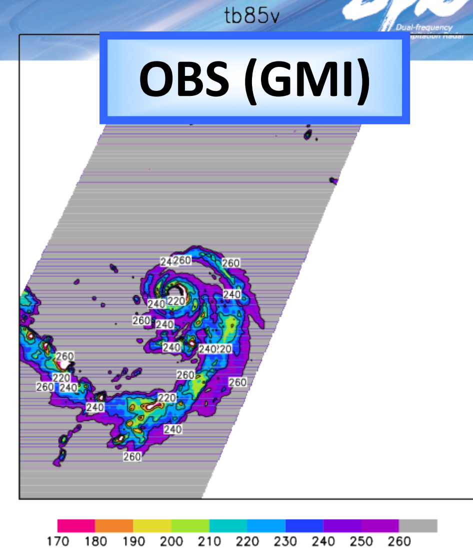
Observed Intensity of Typhoon Halong (1411) and Microwave Observations



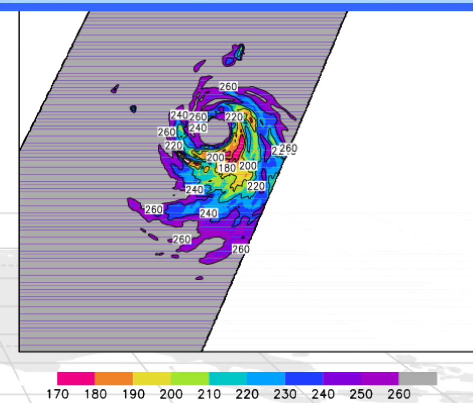
- The rainband structure is much weaker in the model.
- The area of TB < 200 K is larger in the model.
- The area of 210 < TB < 260 is much larger in the observations.

TB85v

OBS (GMI)



Simulated satellite image by JMA/NHM

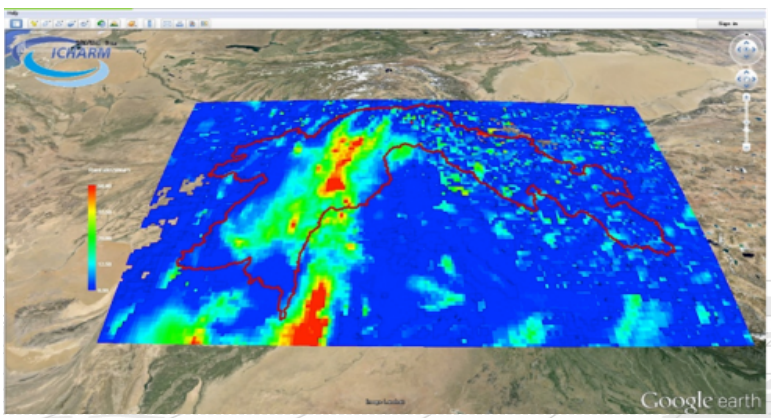


Radiance space-based evaluation is useful in verifying the structure and precipitation-related variables of tropical cyclones simulated in NWP models

UNESCO Pakistan Project for Predicting Floods

- **Under UNESCO-IHP project, JAXA, ICHARM and 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 is now in operation by PMD, and a plan to extend the system to eastern river area is now underway.**

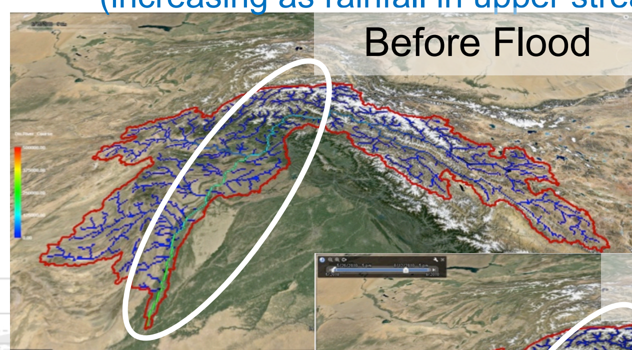
Rainfall by GSMaP



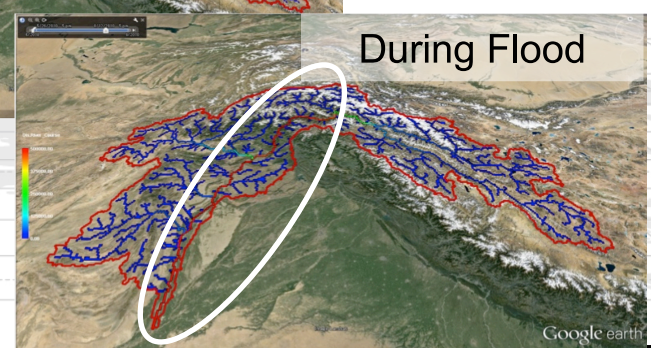
(Area within red line is Indus river basin)

INPUT

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



Discharge of main river is normal (green) before flood

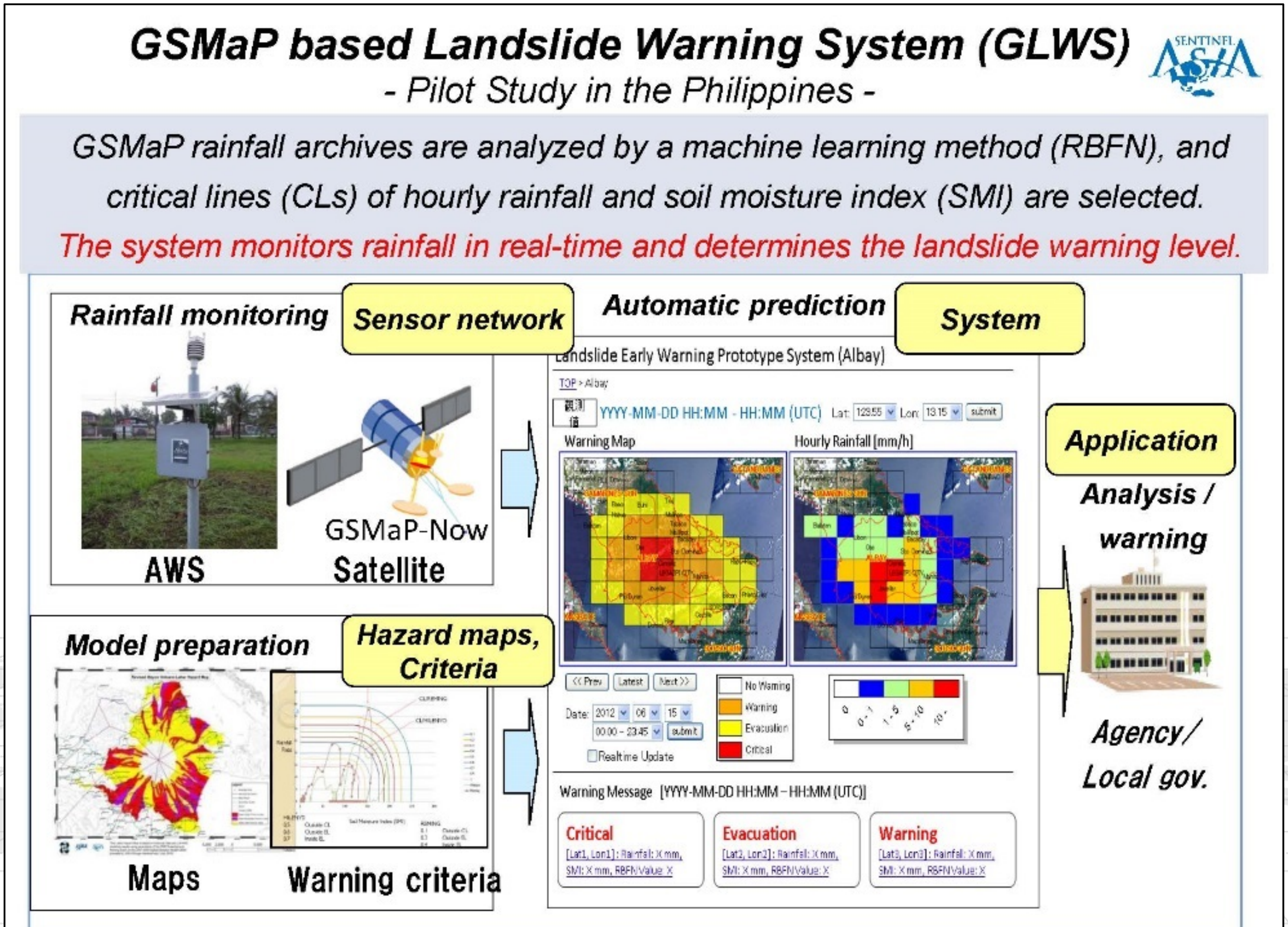


Discharge of main river is largely increased (red) during flood

Example of Indus-IFAS in Pakistan (Image provided by ICHARM)

Landslide Warning System Study

GSMaP-based Landslide Warning System - A prototype Project in the Philippines under the JAXA Sentinel Asia (Arturo S. Daag, PHIVOLCS, Philippine)



2016 Sentinel Asia success story in the Philippines

Effect of GPM-Core Data in the NWP system

- **Okamoto et al. (2016) "** Experimental assimilation of the GPM-Core DPR reflectivity profiles for Typhoon Halong**" was published for *Monthly. Weather Review.***

Assimilation and Forecast experiments using DPR&GMI data for Typhoon Halong confirmed improvement of the position errors of the tropical cyclone in their newly developed MRI/JMA system.

Assimilation experiments

JMA

Exp Name	GMI	KuPR (KuNS)	KaPR (KaHS)	conventional
1.Kuonly		O		O
2.Kaonly			O	O
3.GMIonly	O			O
4.GMI+Ku	O	O		O
5.GMI+Ka	O		O	O
6.GMI+KuKa	O	O	O	O

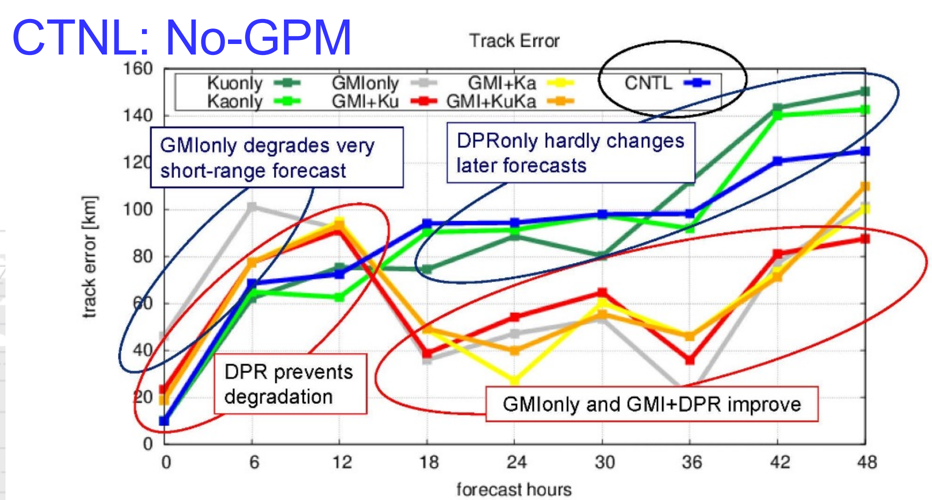
- Implement 6 non-cycle assimilation experiments
- Observation (OB)
  - 2ADPR (NS and HS) attenuation corrected Ze
  - GMI radiance at 10V, 19V, 23V, 37V and 89V channels
  - Conventional data (bogus winds)
- Observation operator
  - Radar simulator : Joint-simulator (Hashino et al. 2013) for Ze
  - Radiative transfer model : Liu (2004) for radiances
- NWP model: JMA-NHM
  - Operational meso-scale model of JMA since 2004 (Saito et al. 2006)
- Assimilation system
  - 5km, 401x401grids, 50-layer, 52 members

Forecast verification : Position error

JMA

12/15

- DPR assimilation yields small errors in the very short-range forecast
- DPR + GMI generates smallest errors overt the entire forecast range



K. Okamoto, K. Aonashi, T. Kubota, T. Tashima, 2016: Experimental assimilation of the GPM-Core DPR reflectivity profiles for Typhoon Halong, *Mon. Wea. Rev.*, 144 (6), 2307-2326.

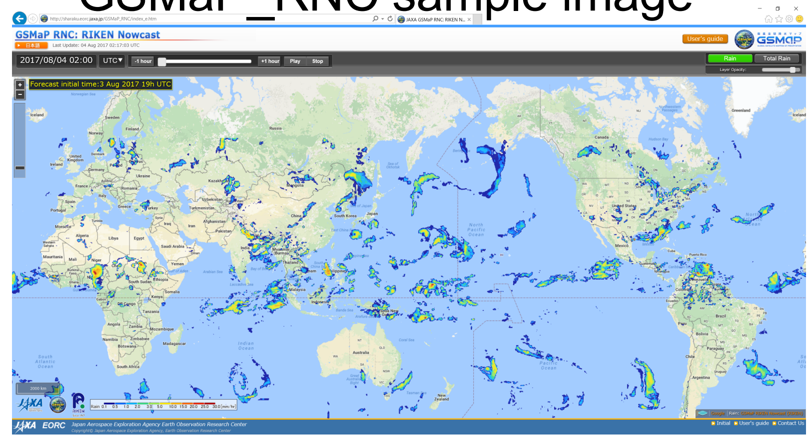
Improvements in GPM-GSMaP

- Main features of "GPM-era GSMaP"(GPM-GSMaP) in V03 (algorithm version 6)
  - GMI which can observe 70N-70S area is installed.
  - Intercalibrated microwave radiometer data (L1c) by NASA is used.
  - Gauge-calibrated GSMaP algorithm (see Mega *et al., poster*) is operated as one of standard outputs (*3-day-after*).
- Update of GSMaP algorithms
  - Improvements in microwave imager algorithm based on AMSR2 precipitation standard algorithm, including new land algorithm, new coast detection scheme, etc.
  - Development of orographic rainfall correction method for warm rainfall in coastal area (*Taniguchi et al., 2013, Shige et al. 2014*)
  - Update of database such as, land surface emission database developed by Japanese DPR/GMI combined team (Drs. Akimoto, Masunaga), etc.
  - Development of microwave sounder algorithm over land

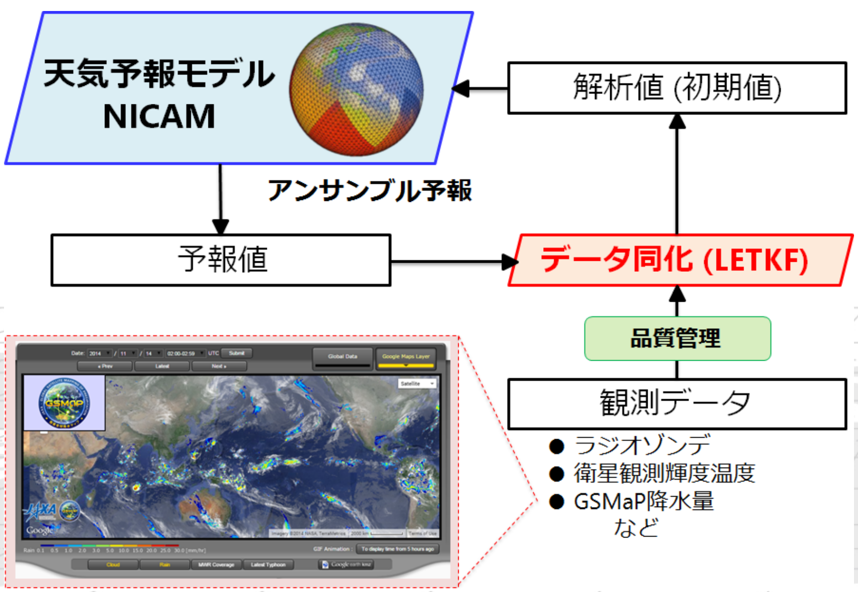
Real-time systems in RIKEN

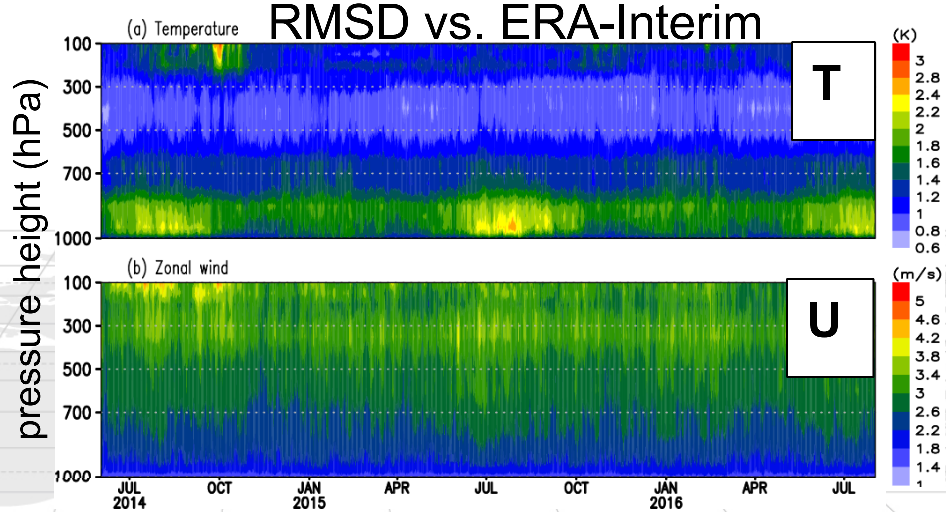
- **GSMaP RIKEN Nowcast (GSMaP_RNC)**
  - System developed (***Otsuka et al.*** 2016, WAF)
  - Real-time operation started from April 2017
- **Real-time NICAM-LETKF**
  - System developed (***Terasaki et al.*** 2015, SOLA)
  - Long-term stability examined (***Terasaki et al.***)
  - Real-time system (***Kanemaru et al.***, in prep)

GSMaP_RNC sample image



➔ https://weather.riken.jp or http://sharaku.eorc.jaxa.jp/GSMaP_RNC





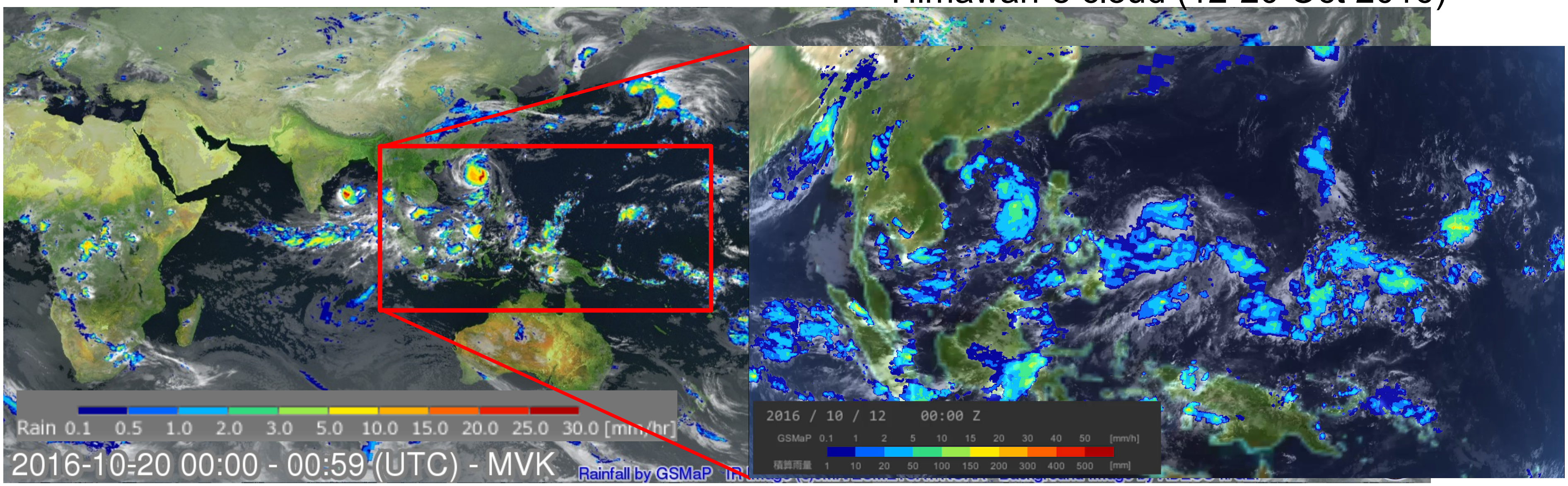
NICAM-LETKF system developed!

➔ Stably running for > 2 years !

Global Satellite Mapping of Precipitation (GSMaP)

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

GSMaP_NRT hourly rain with Himawari-8 cloud (12-20 Oct 2016)



- **GSMaP is a blended Microwave-IR product and has been developed in Japan toward the GPM mission.**
  - **U.S. counterpart is "IMERG"**
  - **GSMaP (v6) data was reprocessed as reanalysis version (GSMaP_RNL) since Mar. 2000 period , and was open to the public on Apr. 2016, and new version, GSMaP (v7) was released on 17 Jan. 2017.**
  - **GSMaP realtime product (GSMaP_NOW) in the domain of GEO-Himawari, GSMaP Riken Nowcast (GSMaP_RNC) data developed by RIKEN/AICS (Otsuka et al. 2016) are now available from JAXA/EORC ftp site.**