Status of the GeoKompsat-2A AMI rainfall rate algorithm

Dong-Bin Shin, Damwon So, Hyo-Jin Park
Department of Atmospheric Sciences,
Yonsei University

Atmospheric Remote Sensing Laboratory

Algorithm Strategy

Well-known assumption in IR-based algorithms

Cloud top temperatures are assumed to be associated with the surface rainfalls.

This assumption usually works for tall clouds with cold cloud top temperatures, but NOT for warm clouds, shallow clouds, and some tall clouds.

Separation of cloud types
Warm/Cold
Shallow/Not-Shallow

Emissivity differences of IR channels for different cloud thicknesses

Various a-priori info
Static databases
Dynamic databases

Acquire data representativeness and add recent and then close info to the target scene

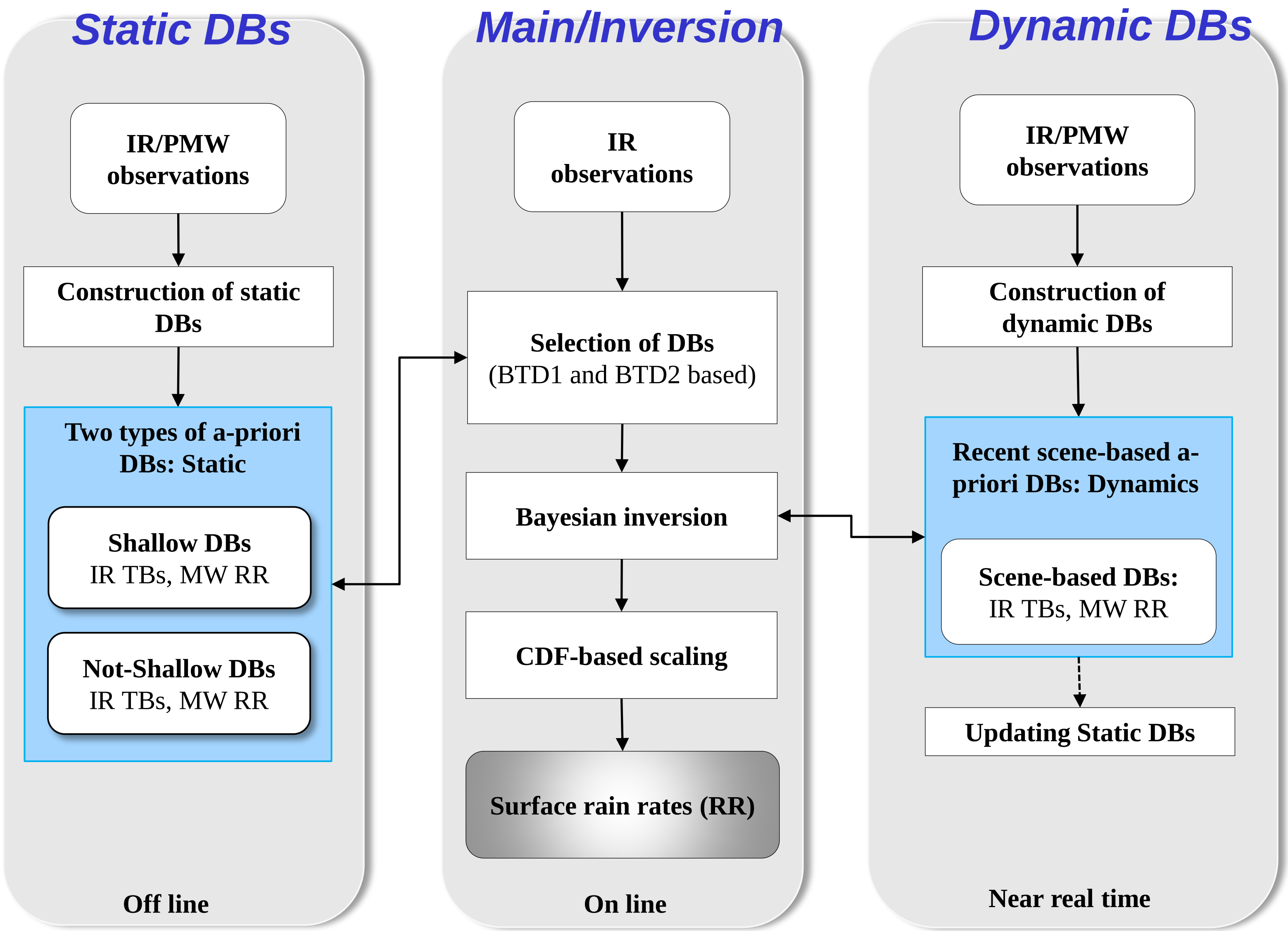
Channels used for GeoKompsat-2A (GK-2A) AMI algorithm

channel	Center wavelength (μm)			
	AMI	ABI	AHI	MI
1(VIS) blue	0.470	0.470	0.46	
2(VIS) green	0.511		0.51	
3(VIS) red	0.640	0.640	0.64	0.675
4(VIS)	0.856	0.865	0.86	
5(NIR)	1.380	1.378		
6(NIR)	1.610(2)	1.610(1)	1.6(2)	
NIR		2.250	2.3	
7(IR)	3.830	3.90	3.9	3.75
8(WV)	6.241	6.185	6.2	
9(WV)	6.952	6.95	7.0	6.75
10(WV)	7.344	7.34	7.3	
11(IR)	8.592	8.50	8.6	
12(IR)	9.625	9.61	9.6	
13(IR)	10.403	10.35	10.4	10.8
14(IR)	11.212	11.20	11.2	
15(IR)	12.364	12.30	12.3	12.0
16(IR)	13.31	13.30	13.3	

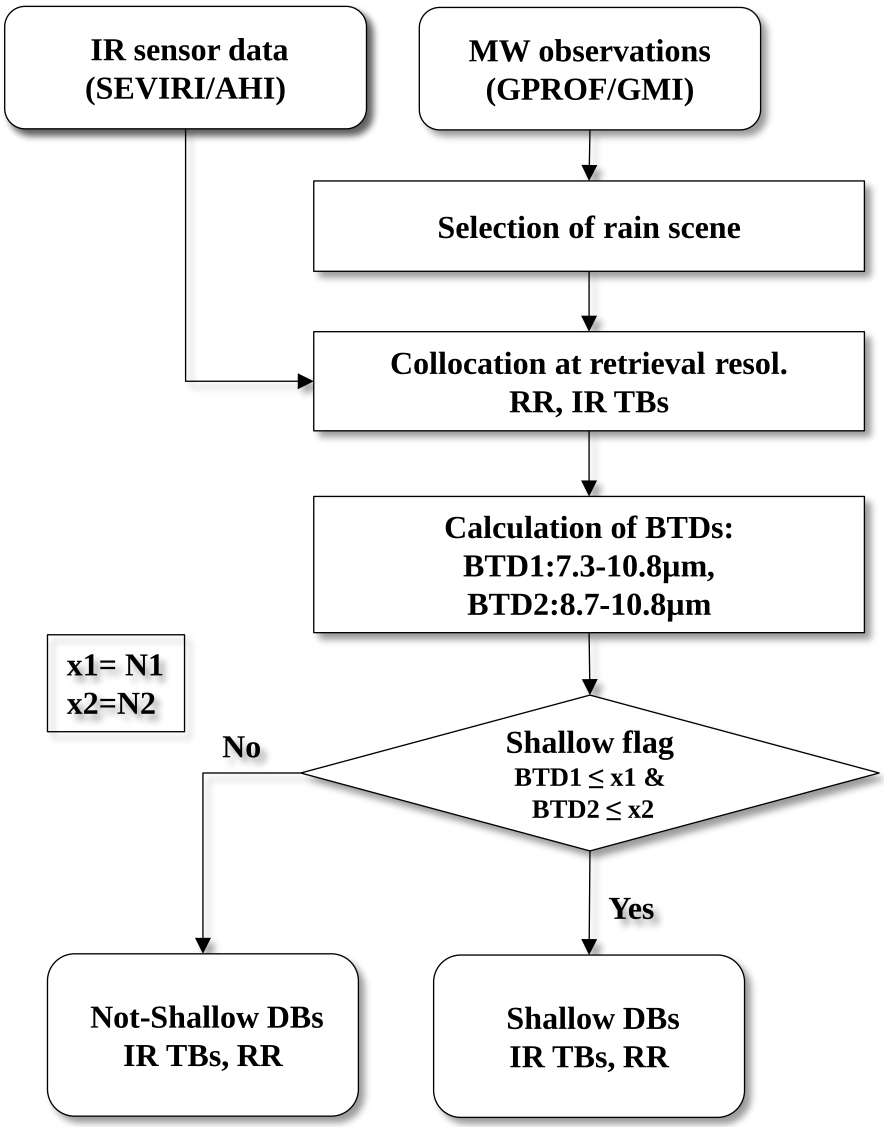
Channel comparisons

ABI : Advanced Baseline Imager(GOES-R)
AHI : Advanced Himawari Imager(Himawari-8/9)
AMI: Advanced Meteorological Imager(GeoKompsat-2A)
MI: Meteorological Imager(COMS)

Flowchart of Rainfall Rate(RR) Algorithm



Construction/Classification of a-priori Databases



DB Classification (For SEVIRI)

#	Latitude	Cloud types	BTD1, BTD2
1	60°S ~ 30°S	Shallow	(e.g.) $Tb_{7.3}$-$Tb_{10.8}$ ≤-12.3 $Tb_{8.7}$-$Tb_{10.8}$ ≤ 1.3
2	30°S ~ EQ		
3	EQ ~ 30°N		
4	30°N ~ 60°N		
5	60°S ~ 30°S	Not-Shallow	Otherwise
6	30°S ~ EQ		
7	EQ ~ 30°N		
8	30°N ~ 60°N		

Proxy Data Sets

Prototype version

GEO IR sensor observations :
Meteosat9 SEVIRI

- Satellite position : 9.5°E/36,000 km
- Spatial resolution : 3 km
- Temporal resolution : 15 min.
- Coverage : 80W-80E, 80S-80N
- Channels in use : IR 6.2, 7.3, 8.7, 10.8, 12.0 μm

LEO MW sensor estimated rainfall rate : **GPROF (Goddard profiling algorithm, 2010v2)**

- Orbital data mapped to 0.25° grid
- SSMIS (DMSP F16, F17, F18) rain rates

Proxy Data Sets

Before the launch of GK2A

GEO IR sensor observations :
Himawari AHI

- Satellite position : 140°E/36,000 km
- Spatial resolution : 2 km
- Temporal resolution : 10 min.
- Coverage : 60E-220E, 80S-80N
- Channels in use : IR 6.2, 7.3, 8.6, 11.2, 12.4 µm

GPM(Global Precipitation Measurement) data : GMI, DPR

- GMI,DPR surface precipitation rate
- Orbital data(Level 2)
- 180°W-180°E, 65°S-65°N

We are in this stage…

After the launch of GK2A

GEO IR sensor observations :
GK-2A AMI

- Satellite position : 128°E/36,000 km
- Spatial resolution : 2 km
- Temporal resolution : 10 min.
- Coverage : 60E-220E, 80S-80N
- Channels in use : IR 6.2, 7.3, 8.6, 11.2, 12.4 µm

GPM(Global Precipitation Measurement) data : GMI, DPR

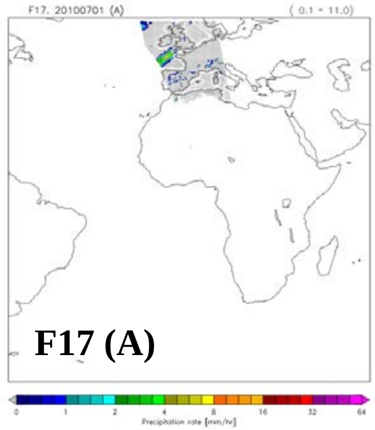
- GMI,DPR surface precipitation rate
- Rain rate form the parametric Algorithm (Yonsei version) for MW rainfalls (possible).
- Orbital data(Level 2)
- 180°W-180°E, 65°S-65°N

Collocation of Proxy Data (for prototype)

- Time collocation
  - SEVIRI observes for 12 minutes
  - ex) 2010.7.1.16:45 UTC → 16:45~16:57 UTC
  - Find GPROF rain pixels matched with SEVIRI observation time and composite(average) the pixels.

- Spatial collocation
  - SSMIS - GPROF Data collocated at the SEVIRI pixels (3km)

ex)



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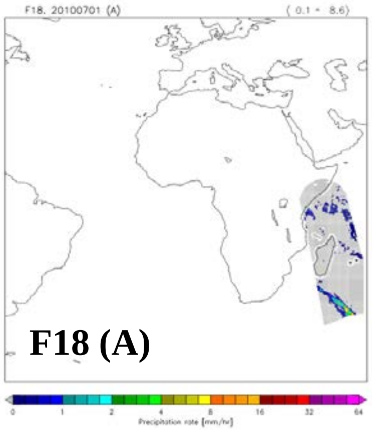
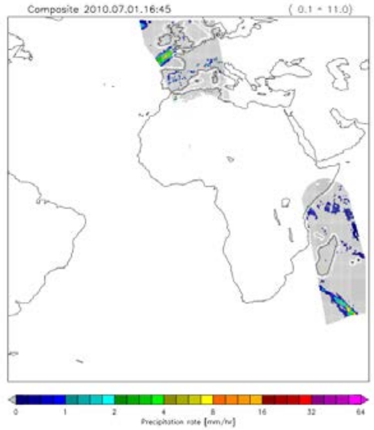
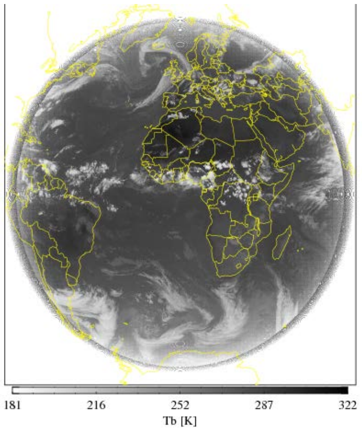




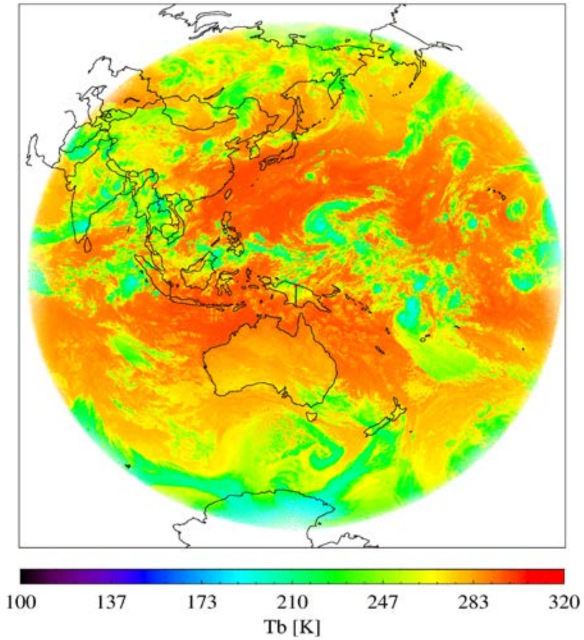
GPROF composite field
2010.7.1.16:45UTC



SEVIRI 10.8 μm Tb
2010.7.1.16:45UTC

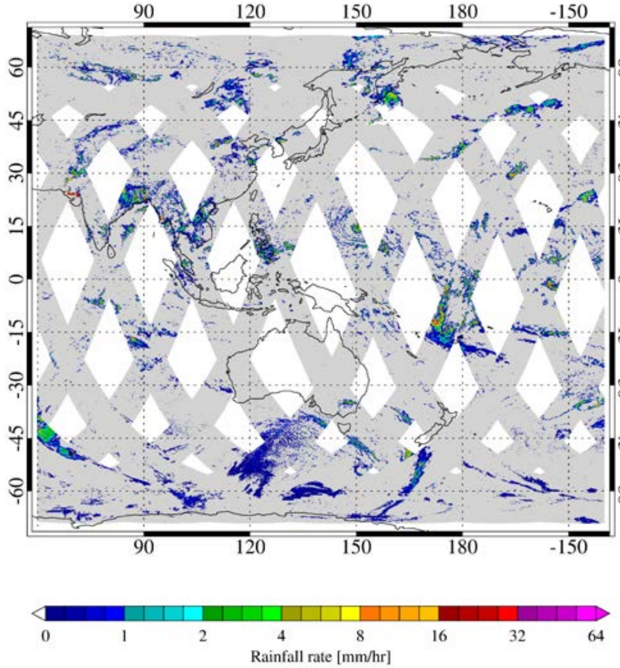
Collocation of Proxy Data (for working on version)

AHI ch14(11.2) TB



AHI 11.2 µm Tb
2015.08.01.21.10 UTC

GMI precipitation



GMI(GPROF) precipitation
2015.08.01

- Time collocation
  - AHI observes for 10 minutes
  - Find GMI rain pixels matched with AHI observation time.
- Spatial collocation
  - AHI data collocated at the GMI pixels

Separation of Cloud Types

- The cloud emissivity can be different as a function of wavelength if cloud thickness is less than about 500m.
- The thick clouds (>500m) can have a similar emissivity (almost 1)

Shallow and not-shallow clouds separation

based on brightness temperature differences (BTD)

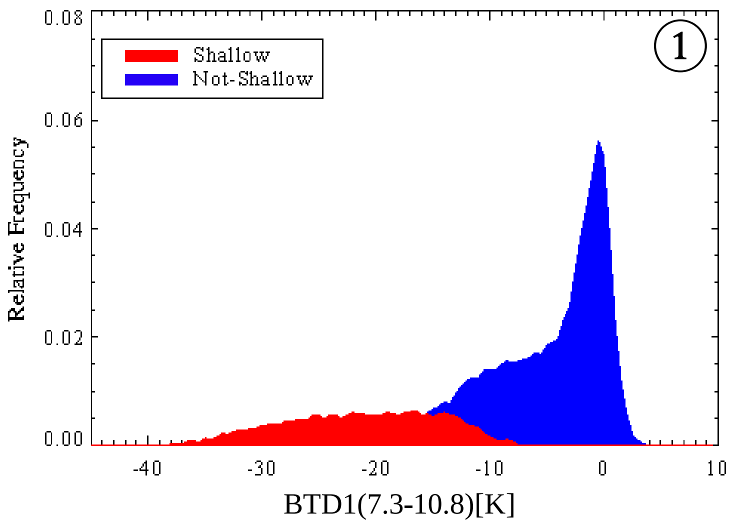
BTD1=Tb7.3-Tb10.8μm, BTD2=Tb8.7-Tb10.8μm (SEVIRI/PR)
BTD1=Tb7.3-Tb11.2μm, BTD2=Tb8.6-Tb11.2μm (AHI/DPR)

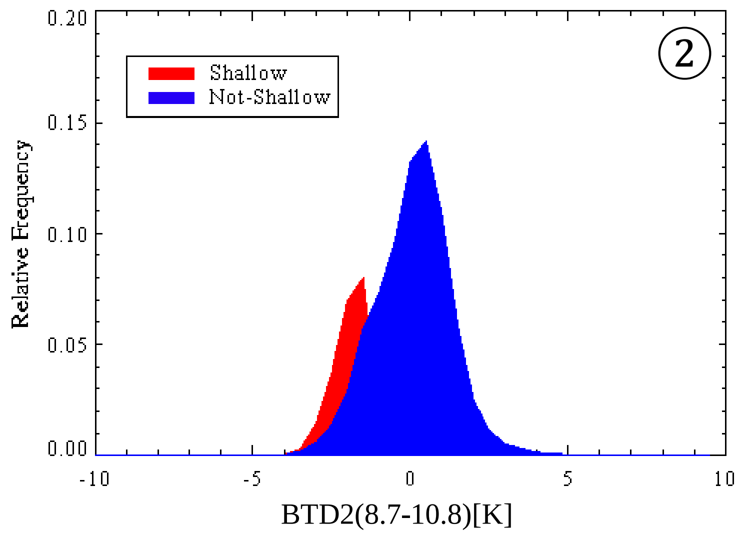
- Shallow rain threshold values are obtained using **TRMM PR / GPM DPR** observations (Shallow rain flag).
- The threshold values are based on **TRMM PR (2A23, 2A25)/ GPM DPR** and TBs at **SEVIRI(AHI)**'s 5 channels for the period 2010.7.1~7.31/2015.8.1~8.15.
- PR/DPR defines **shallow rain if the storm height is lower than the height of freezing level by 1km**

Shallow/Not-shallow Cloud Discrimination

with SEVIRI & PR over Africa

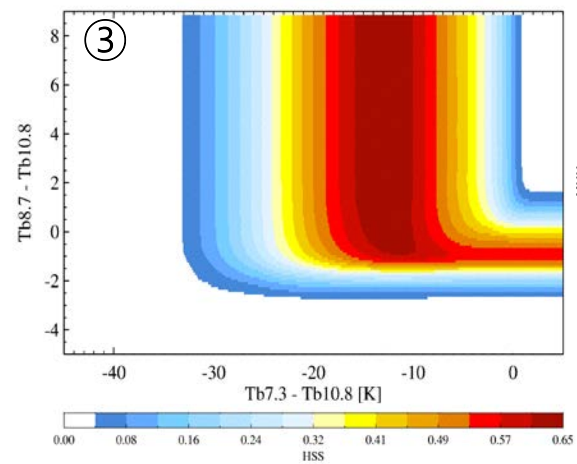
- PDFs of BTD1,BTD2

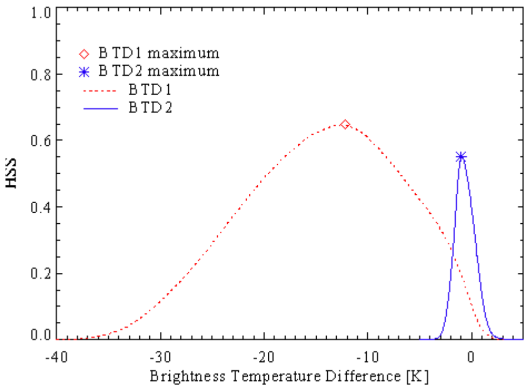




binsize = 0.5 K

- Threshold values optimized from Heidke Skill Score (HSS)





Constrain	① BTD1	② BTD2	③ BTD1 &BTD2
Threshold (K)	-12.3	-1.0	-12.3, 1.3
HSS	0.662	0.575	0.664

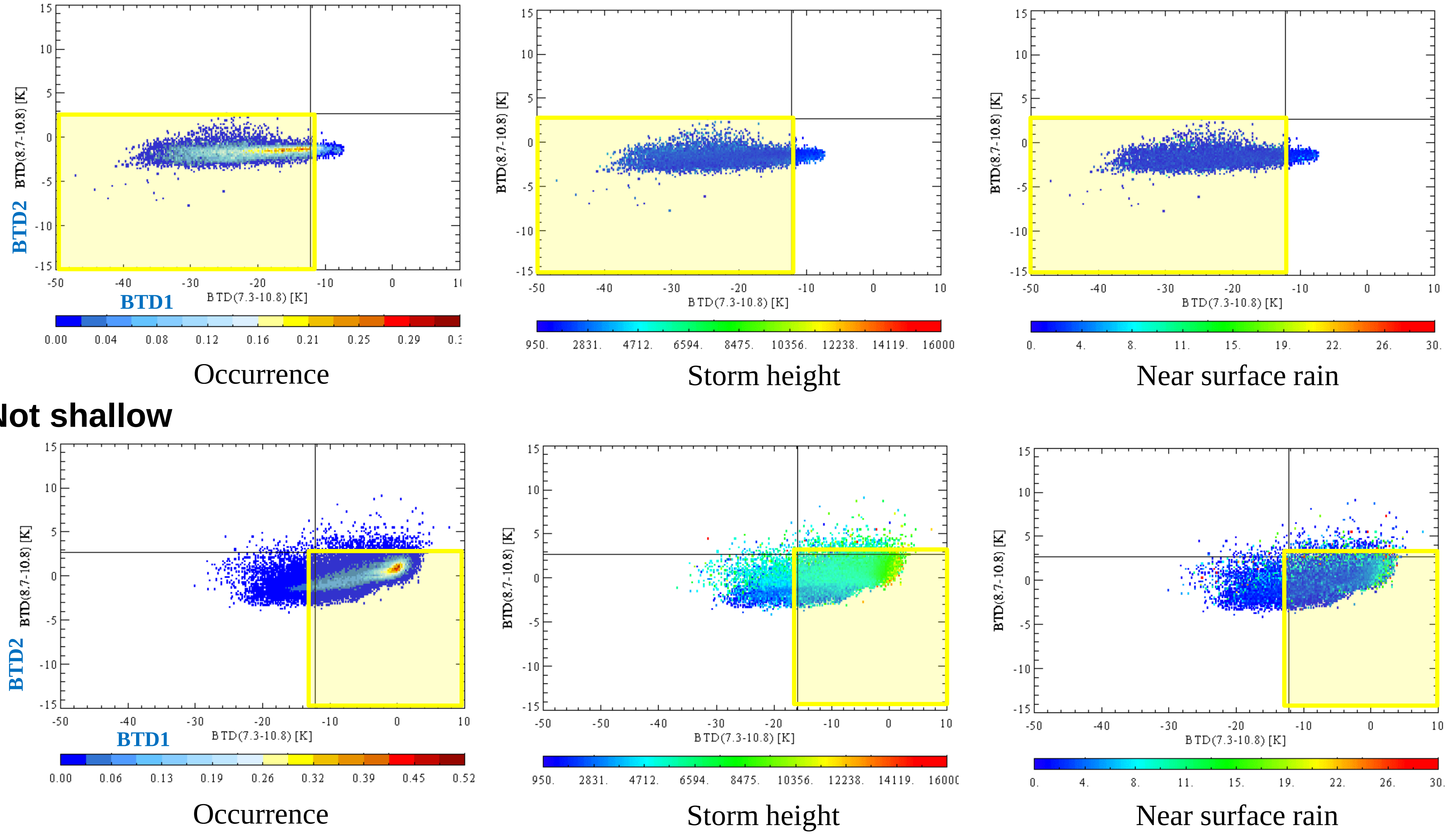
- ➢ **BTD1 is a good separator.**
- ➢ **Adding BTD2 increases the skill score slightly.**

Shallow/Not-shallow Cloud Discrimination
with SEVIRI & PR over Africa

Verification of the thresholds

Shallow

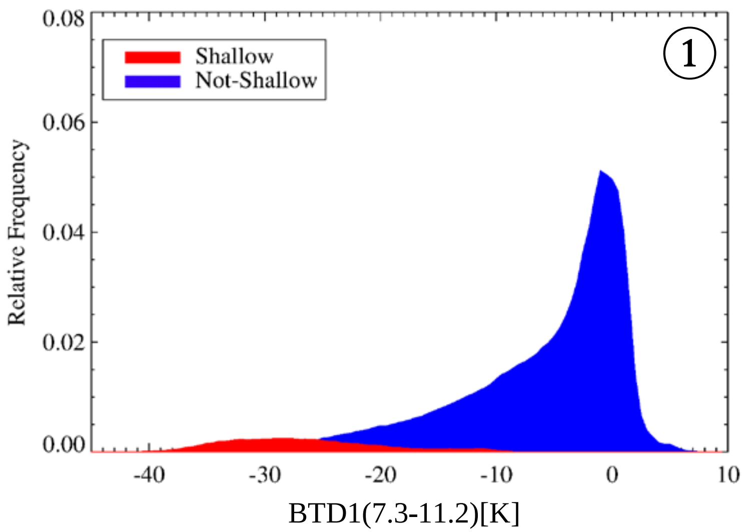
Not shallow

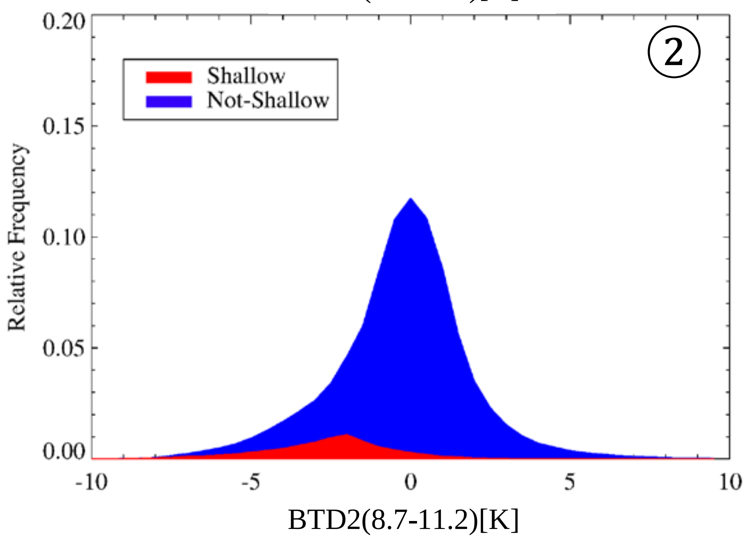


Shallow/Not-shallow Cloud Discrimination

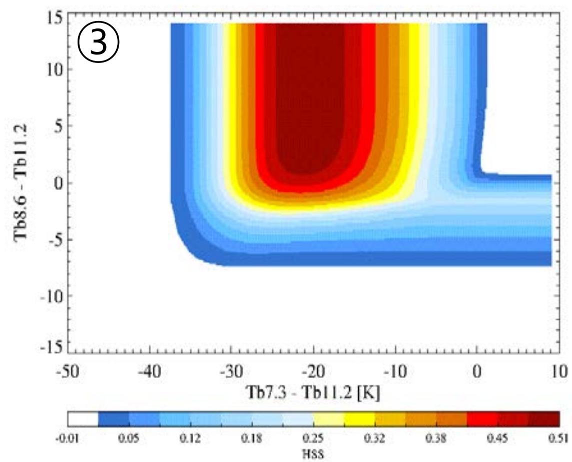
with AHI & DPR over Asia

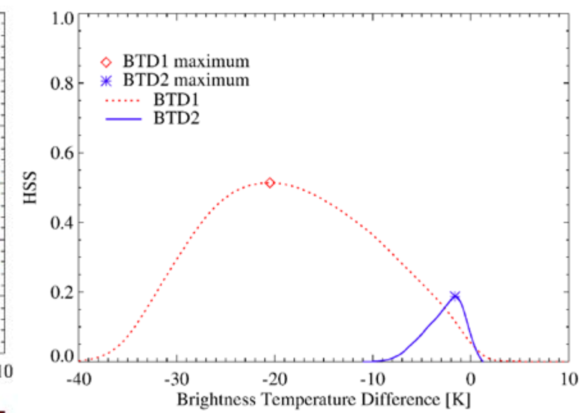
- PDFs of BTD1,BTD2





- Threshold values optimized from Heidke Skill Score (HSS)





Constrain	① BTD1	② BTD2	③ BTD1 &BTD2
Threshold (K)	-17.4	-1.6	-20.5, 7.5
HSS	0.583	0.187	0.514

➢ **Using BTD1 is enough**

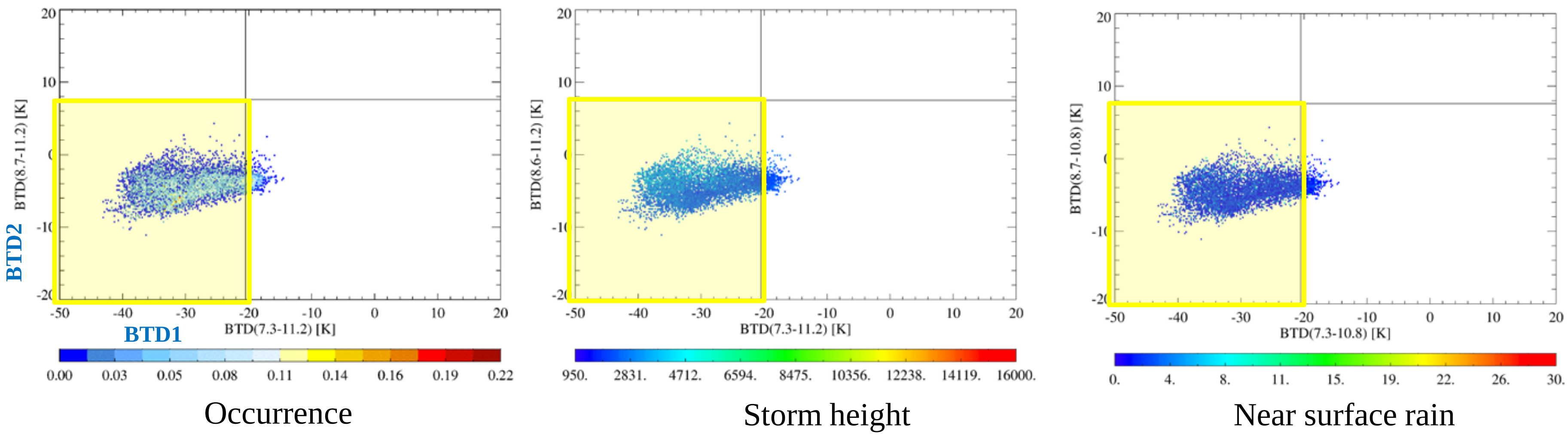
binsize = 0.5 K

Shallow/Not-shallow Cloud Discrimination

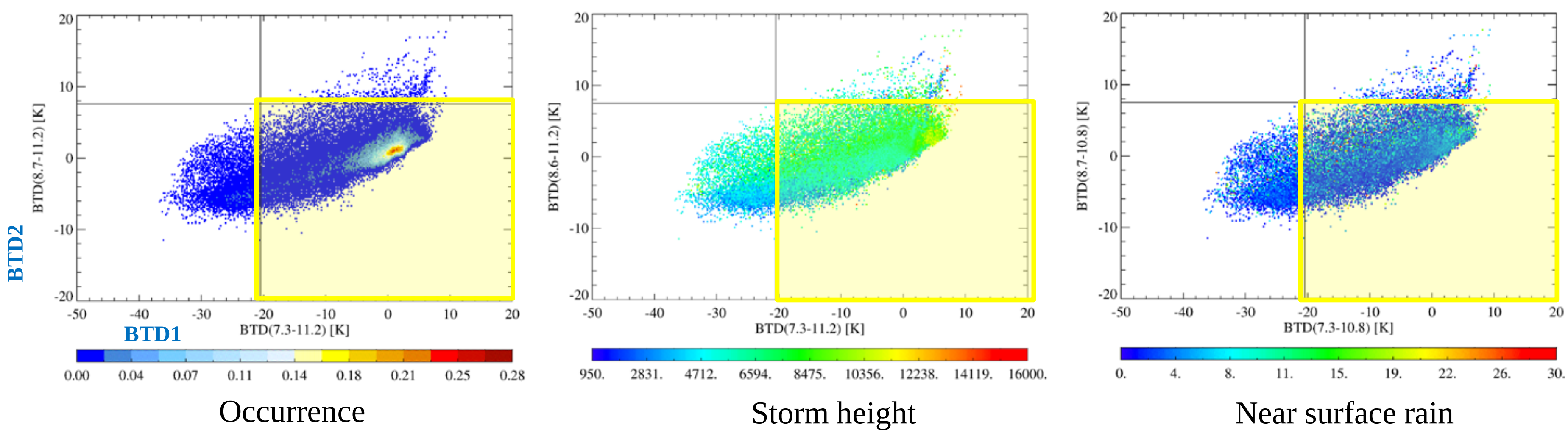
with AHI & DPR over Asia

Verification of the thresholds

Shallow



Not shallow

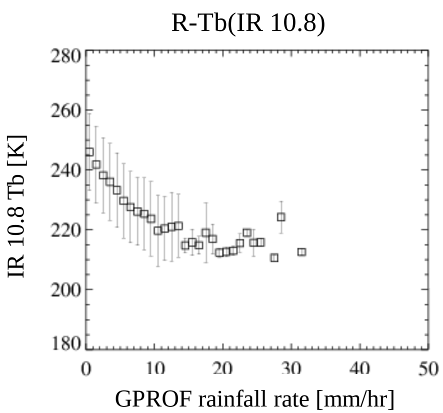


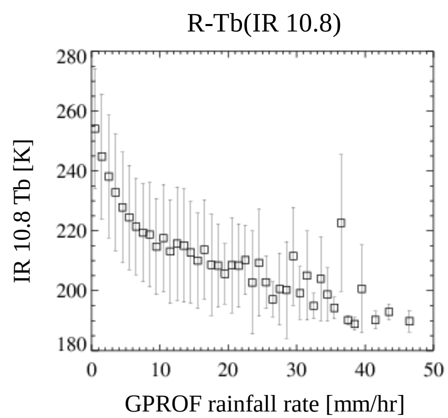
Characteristics of the Static Databases

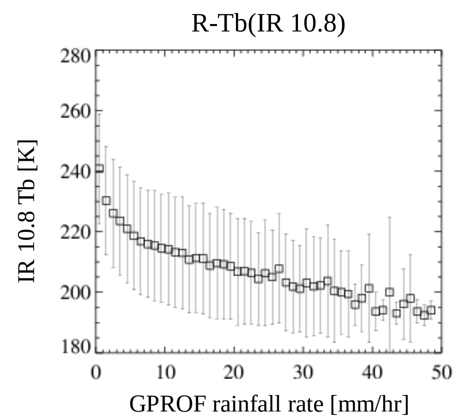
(with SEVIRI & PR over Africa)

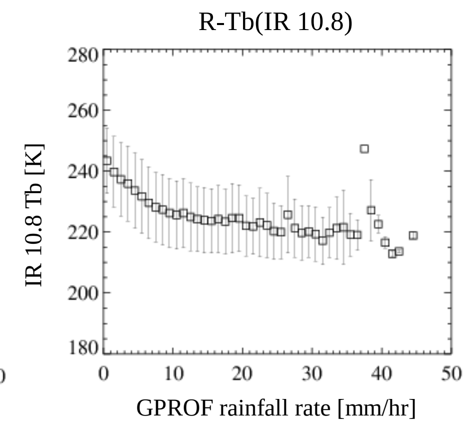
R-Tb (10.8μm) relationships for cloud types and latitudinal bands

Not Shallow

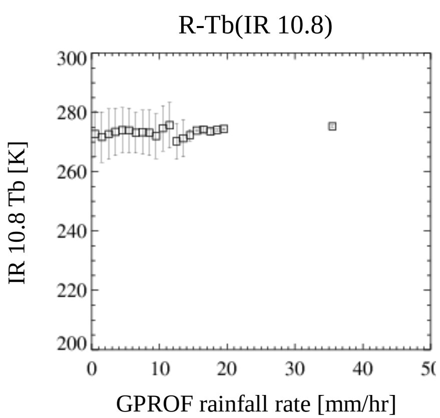


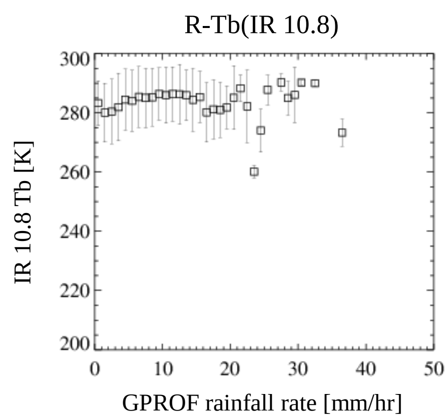


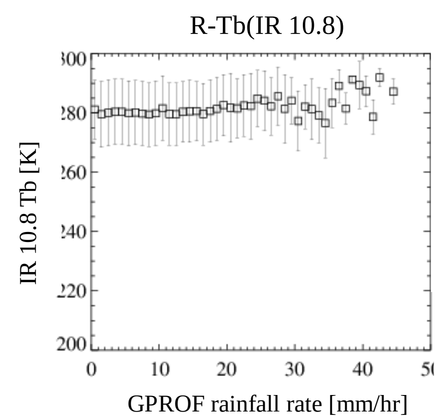


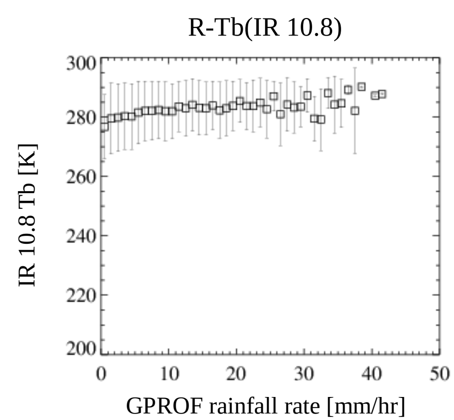


Shallow









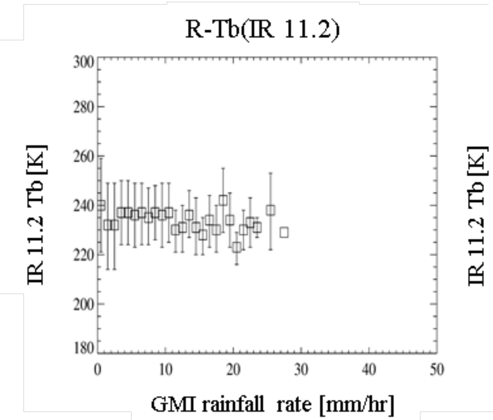
60°S~30°S | **30°S~EQ** | **EQ~30°N** | **30°N~60°N**

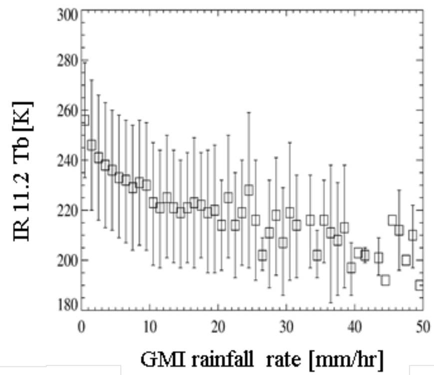
Characteristics of the Static Databases
(with AHI & DPR over Asia)

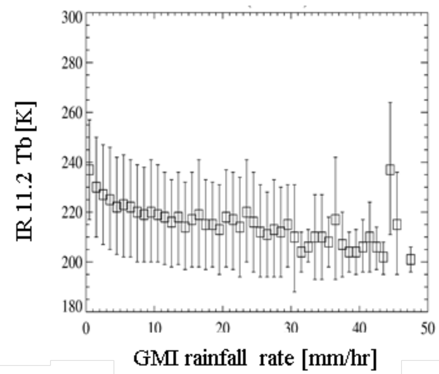
R-Tb (11.2μm) relationships for cloud types and latitudinal bands

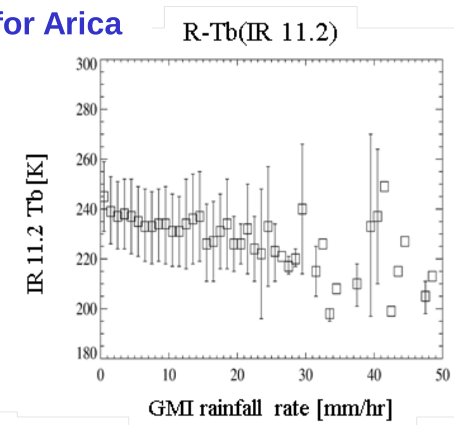
Not Shallow

R-Tb relationships are not as clear as those obtained for Arica

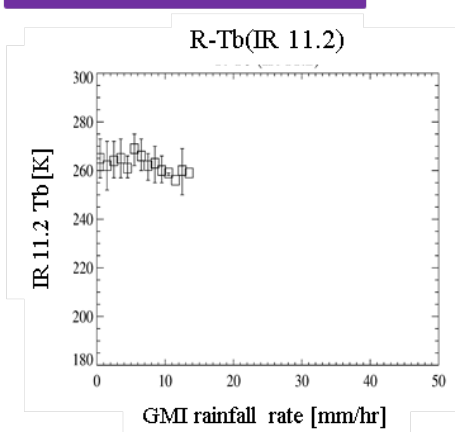


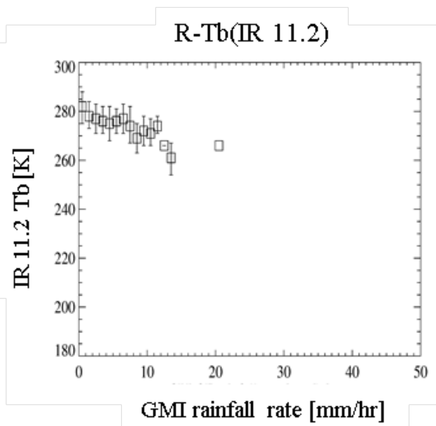


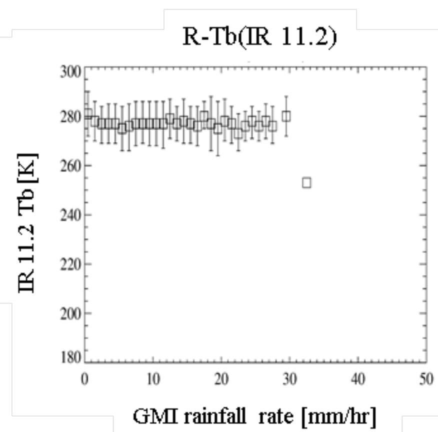


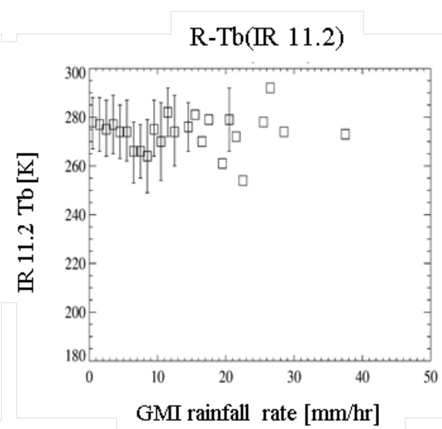


Shallow









70°S~30°S | **30°S~EQ** | **EQ~30°N** | **30°N~70°N**

Inversion: Bayesian Approach

The posterior probability,
Probability to get **h** given **b**:

$$\mathrm{P}(\mathbf{h}\,|\,\mathbf{b}) \propto \mathrm{P}(\mathbf{b}\,|\,\mathbf{h})\,\mathrm{P}(\mathbf{h})$$

- **h:** the state vector (rain parameters)
- **b:** the measurement vector (the set of brightness temperatures from AMI)

The conditional probability, a probability to get **b** given **h**, (Rodgers, 2000),

$$\mathrm{P}(\mathbf{b}\,|\,\mathbf{h}) = \frac{1}{(2\pi)^{P/2}\left|\mathbf{C}_{\mathrm{b}}\right|^{1/2}} \exp\left\{-\frac{1}{2}[\mathbf{b}-\mathbf{b}_{\mathrm{m}}(\mathbf{h})]^{\mathrm{T}}\,\mathbf{C}_{\mathrm{b}}{}^{-1}[\mathbf{b}-\mathbf{b}_{\mathrm{m}}(\mathbf{h})]\right\},$$

$\mathbf{b}$: measurement vector ,

$\mathbf{b}_m$: modeled measurement vector

$\mathbf{C}_{\mathrm{b}}$: covariance matirx of $[\mathbf{b}-\mathbf{b}_{\mathrm{m}}(\mathbf{h})]$

For our case based on the observation, $\mathrm{P}(\mathbf{h}) = 1/N$: the probability to have **h**

$$\mathrm{P}(\mathbf{b}\,|\,\mathbf{h})\,\mathrm{P}(\mathbf{h}) =$$

$$\frac{1}{(2\pi)^{P/2}\left|\mathbf{C}_{\mathrm{b}}\right|^{1/2}} \exp\left\{-\frac{1}{2}[\mathbf{b}-\mathbf{b}_{\mathrm{m}}(\mathbf{h})]^{\mathrm{T}}\,\mathbf{C}_{\mathrm{b}}{}^{-1}[\mathbf{b}-\mathbf{b}_{\mathrm{m}}(\mathbf{h})]\right\} \cdot \frac{1}{N}$$

The retrieval is to evaluate the expectation for **h** as given by $\mathrm{E}(\mathbf{h}) = \dfrac{\int \mathbf{h}\,\mathrm{P}(\mathbf{h}\,|\,\mathbf{b})\,d\mathbf{h}}{\int \mathrm{P}(\mathbf{h}\,|\,\mathbf{b})\,d\mathbf{h}}.$

Scaling Rainfall Range

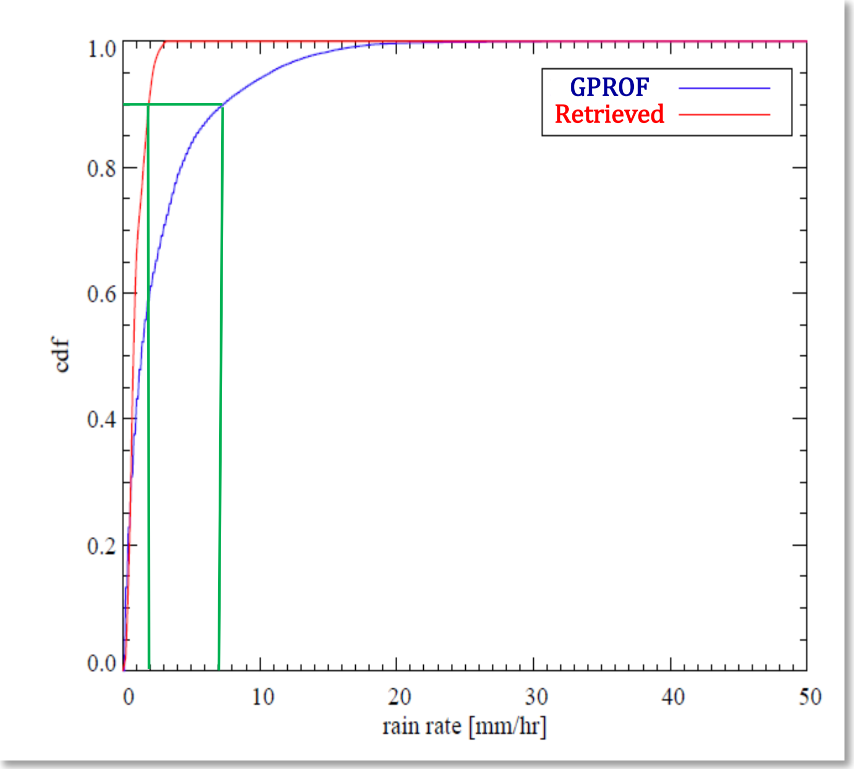
- The AMI rainfall algorithm tends to estimate rain rates lower than those from the PMW algorithm. It is because the rain rates in the *a-priori* databases are originated from the microwave sensor with lower spatial resolutions, equivalently larger footprints.

- Assume cumulative distribution functions of the retrieved rain rates and GPROF rain rates are equal.

$$\int_0^{R_S} P(R_S)dR_S = \int_0^{R_O} P(R_O)dR_O$$

Rs : Retrieved rain rate

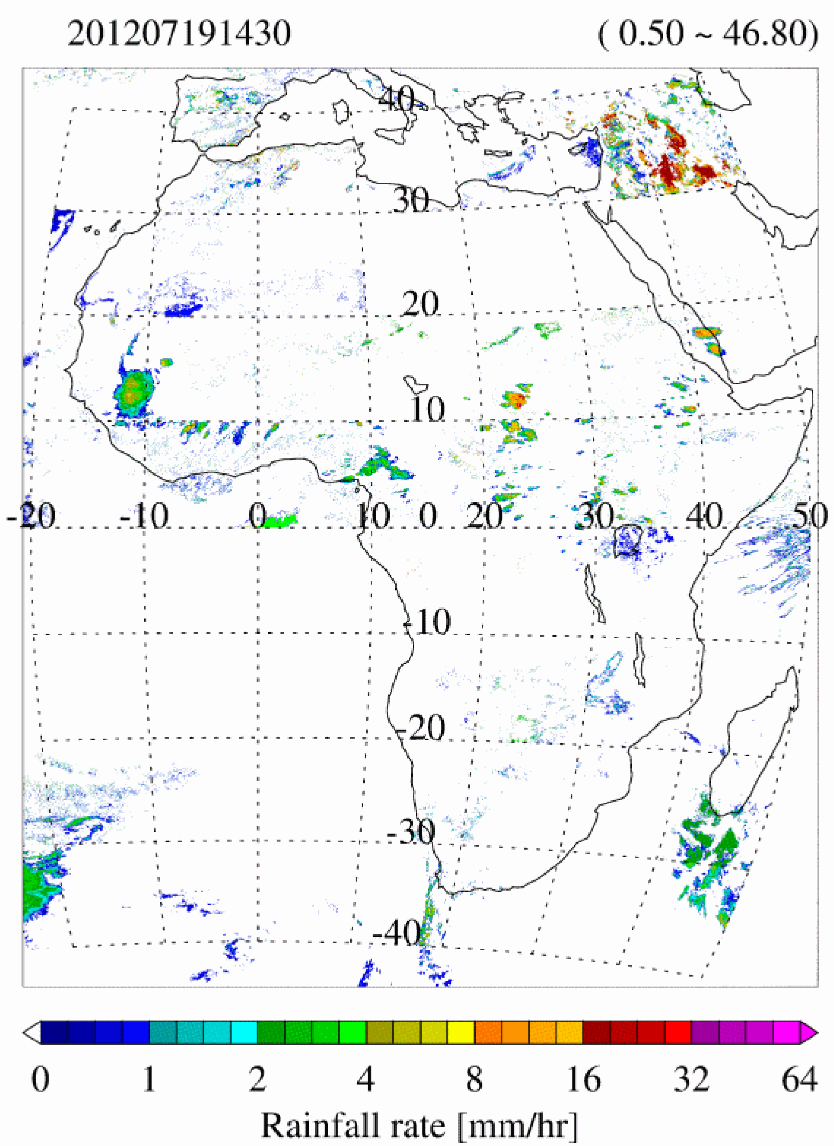
Ro : GPROF rain rate



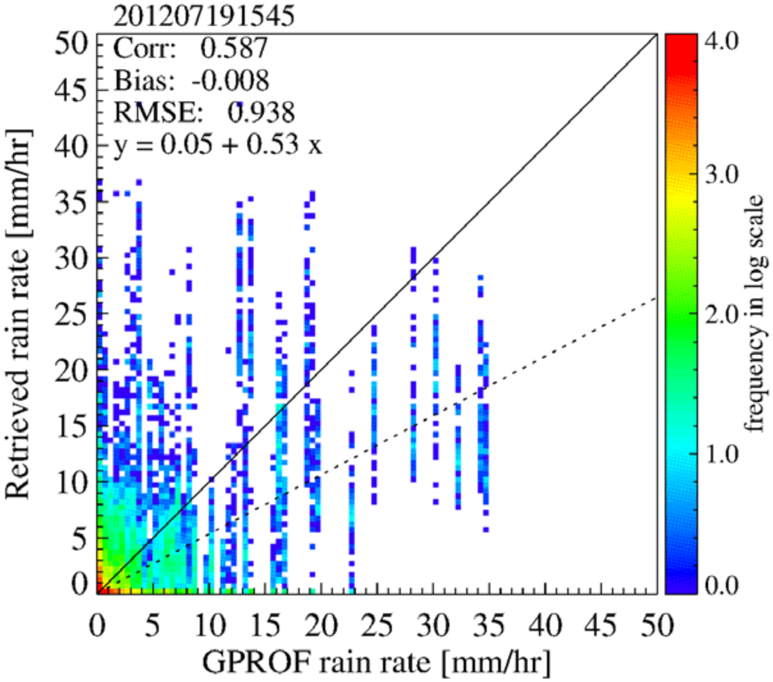
<CDF matching>

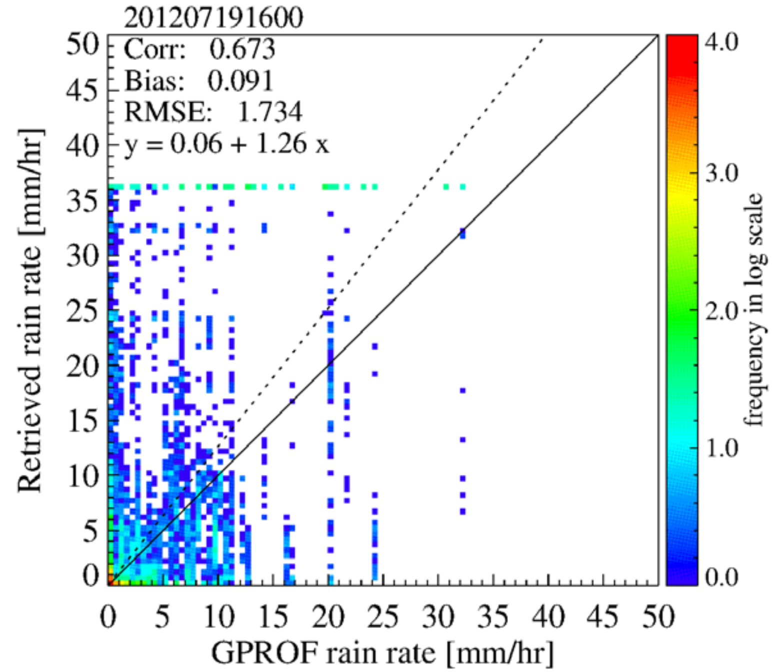
- LUTs are prepared at every 10° latitude bands.

Retrieval Examples



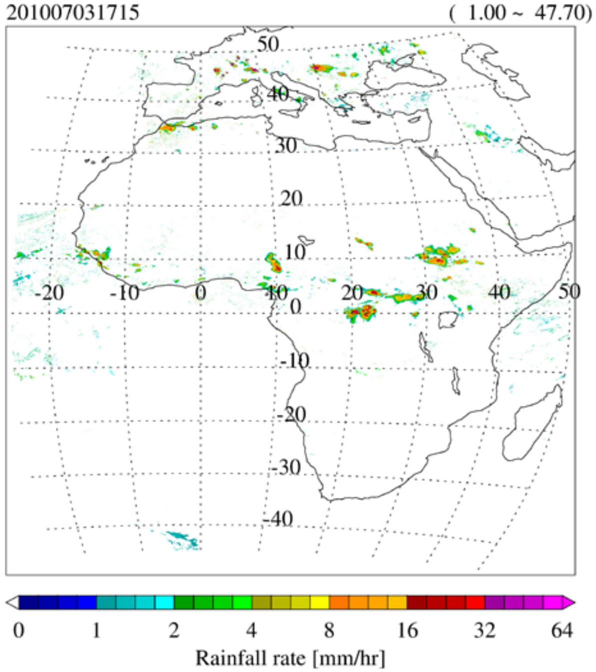
Validation Statistics for the examples



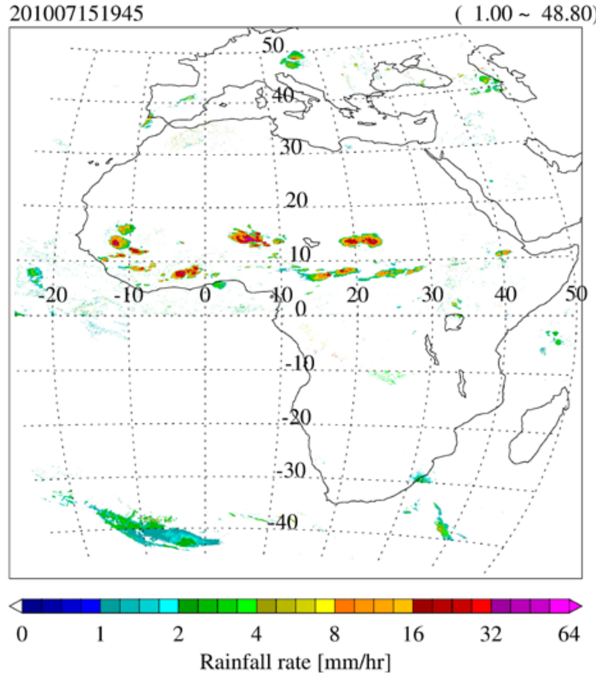


Method / Scene	Scalar Accuracy Measures			Categorical Accuracy Measures			
	Corr	**Bias**	**RMSE**	**POD**	**FAR**	**HSS**	**Slope**
2012.07.19.15:45	**0.587**	**-0008**	**0.938**	**0.307**	**0.466**	**0.356**	**0.529**
2012.07.19.16:00	**0.673**	**0.091**	**1.73**	**0.3224**	**0.573**	**0.344**	**1.256**

Preliminary Results with Dynamic Database

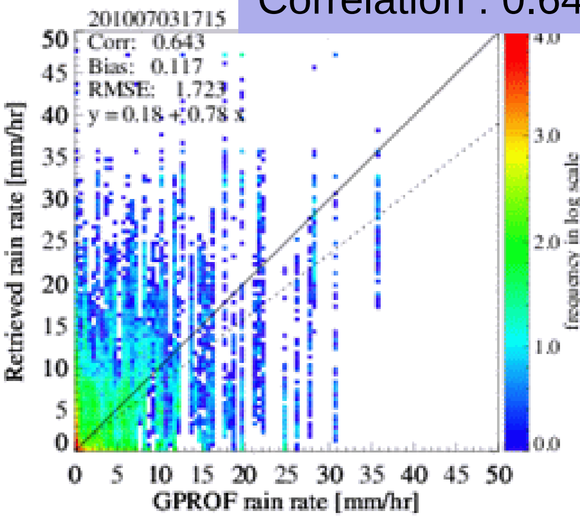


Static DBs +
Dynamic DBs (-1 and -2 days)

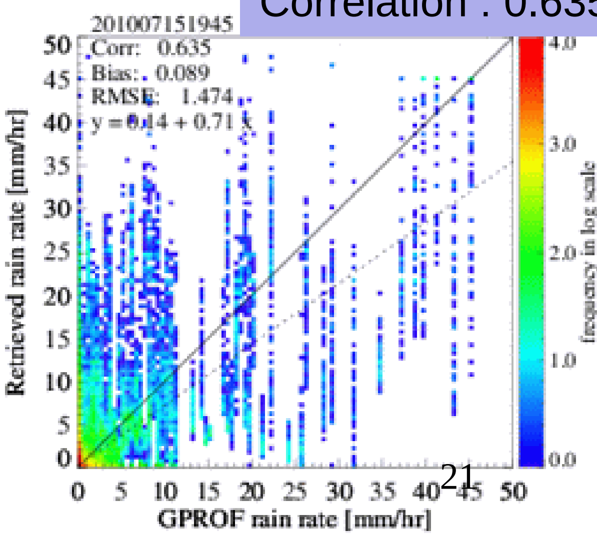


Static DBs +
Dynamic DBs (-2, -3 days)

Correlation : 0.643



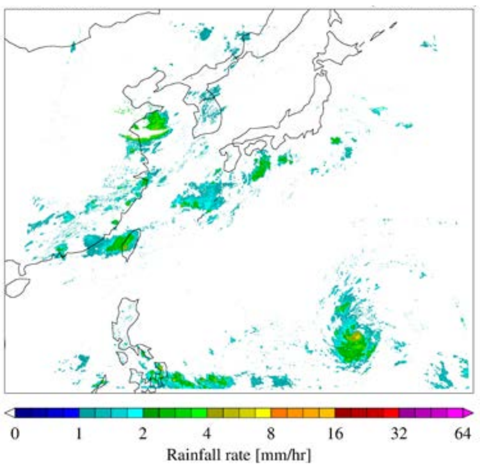
Correlation : 0.635



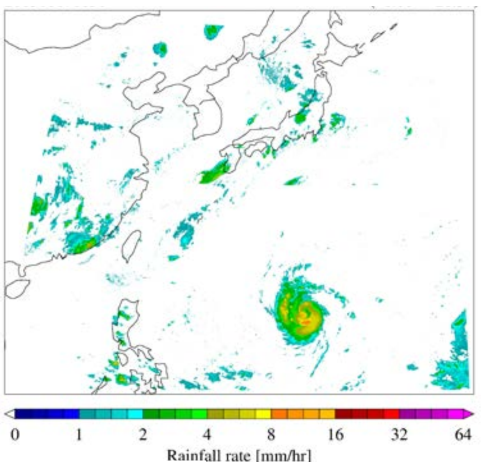
Preliminary Retrieval Results for AHI

(without scaling process)

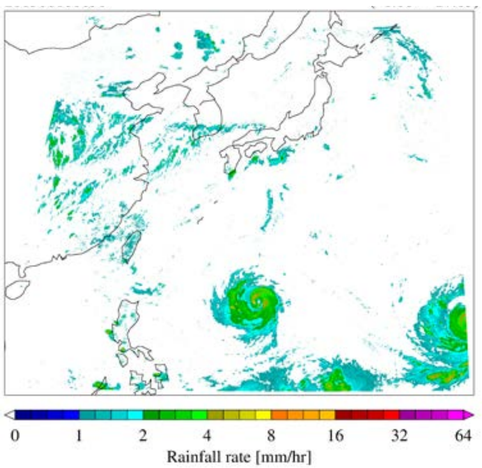
2015.08.16.05:50 UTC



2015.08.17.11:50 UTC



2015.08.18.06:30 UTC



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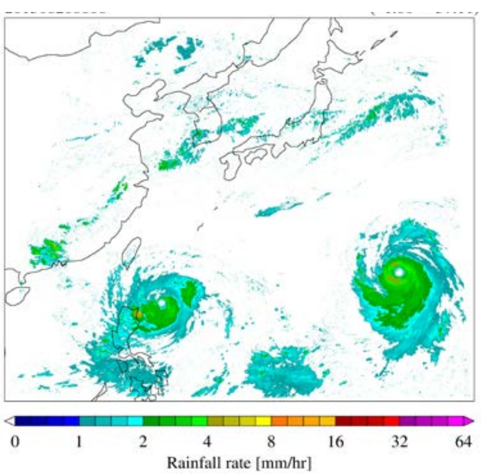

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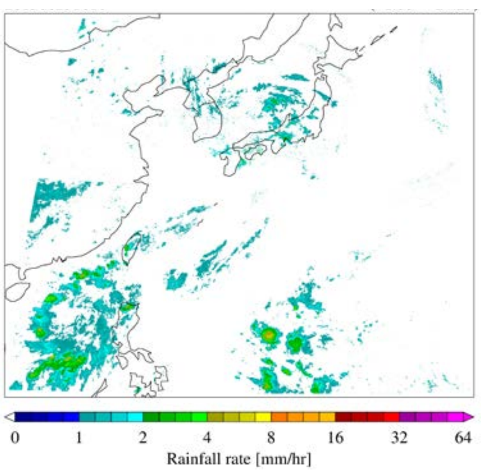


Ongoing Works

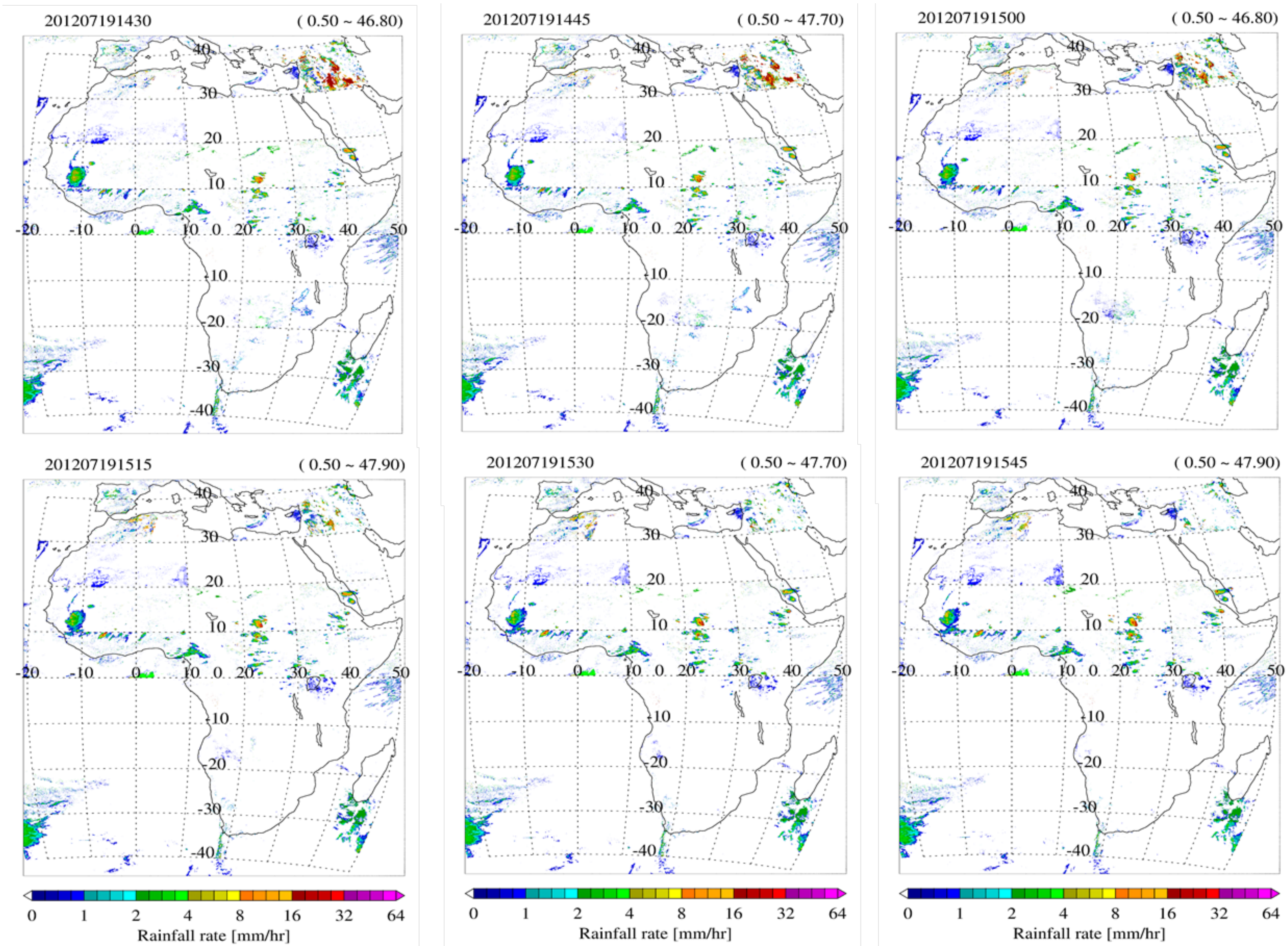
Current status summary:

- Theoretical basis and the algorithm frame including construction of a-priori DBs and inversion are developed.
- Retrievals with limited databases produce rain fields as a prototype

Ongoing works

- Working with the proxy datasets for longer periods (more than 6 months)
  - Thresholds of BTD1 and BTD2
  - Re-defining the latitudinal bands for database classification
  - Adjustments AHI data to AMI
- Enhancement of the dynamic databases
  - Retrieval of rainfall rates using static and dynamic databases
  - Updating the static database using the dynamic database
- Improvement of the scaling method
- Validation of the Algorithm: GPM GMI, DPR

Retrieval Examples



Retrieval Examples