Roles of microphysics in cloud resolving models in passive microwave remote sensing of precipitation over ocean

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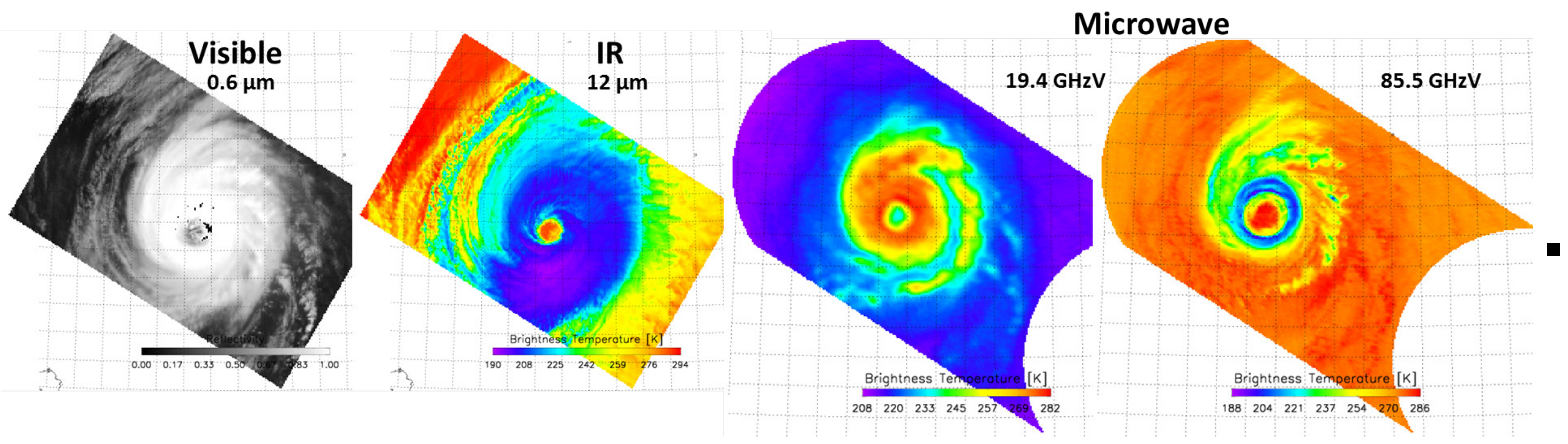
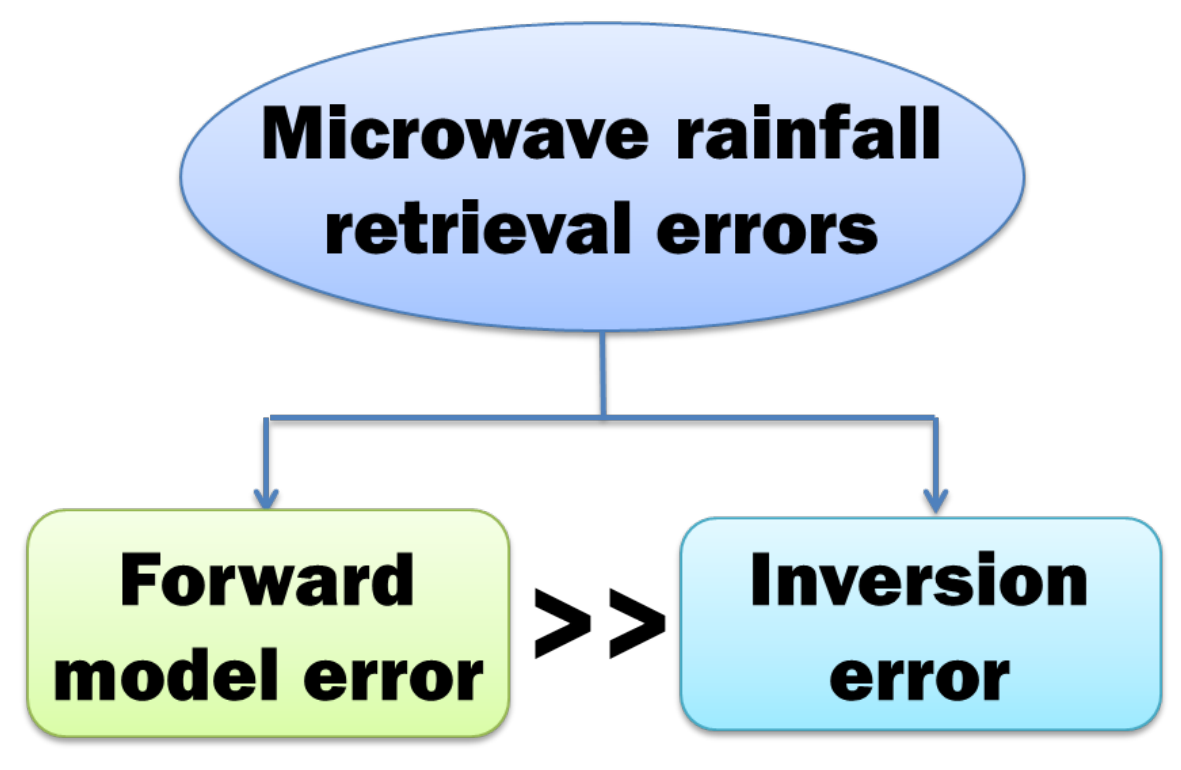
1. Remote sensing of precipitation



Observed brightness temperatures (TBs) for typhoon Sudal (2004) from TRMM satellite measurement.

- Microwave sensors are known as the most accurate precipitation measurement owing to its physical relationship with precipitation particles.
- Frozen hydrometeors scatter upwelling radiations while cloud and rain droplets emit microwave radiation. These two properties are distinct depending on the frequency.

2. Uncertainty of microwave remote sensing of precipitation



Microwave rainfall retrieval errors

Forward model error >> **Inversion error**

Most of current microwave rainfall algorithm depends on the cloud resolving model (CRM) in the generation of *a-priori* DB!

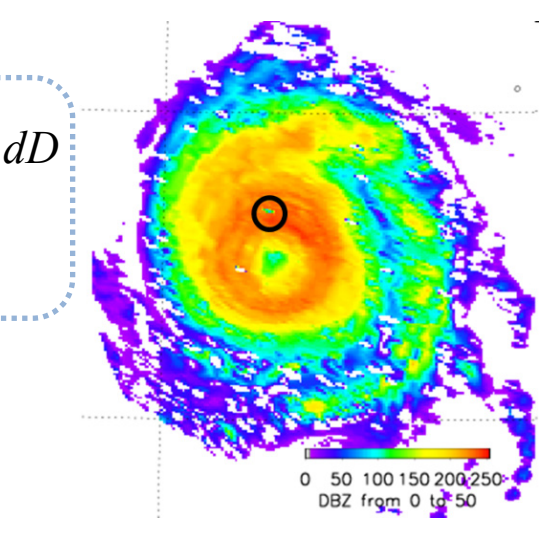
- **Forward model error** : Radiative transfer model, surface variability, **bulk microphysics**
- The largest uncertainty is introduced by the cloud model itself. **Assumptions in the microphysical properties** and related characteristics of hydrometeors distributions **are connected to microwave rainfall retrieval errors**.

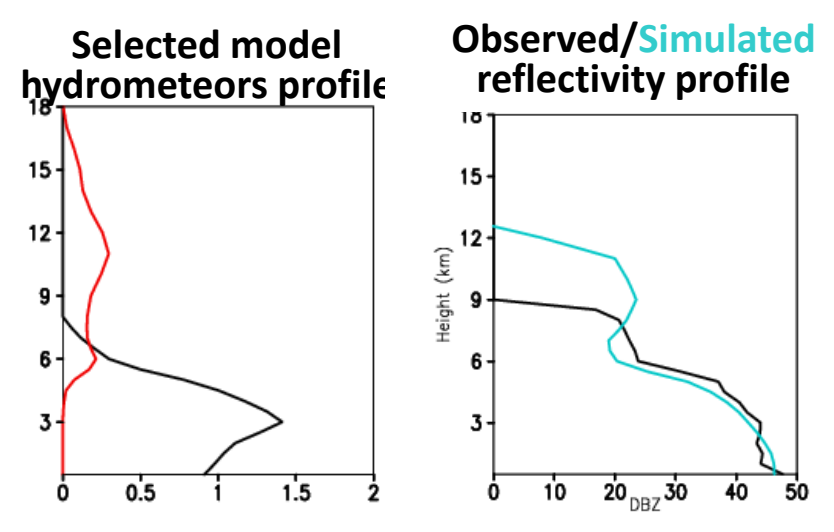
3. Parametric rainfall algorithm (GPROF v7 Ocean algorithm)

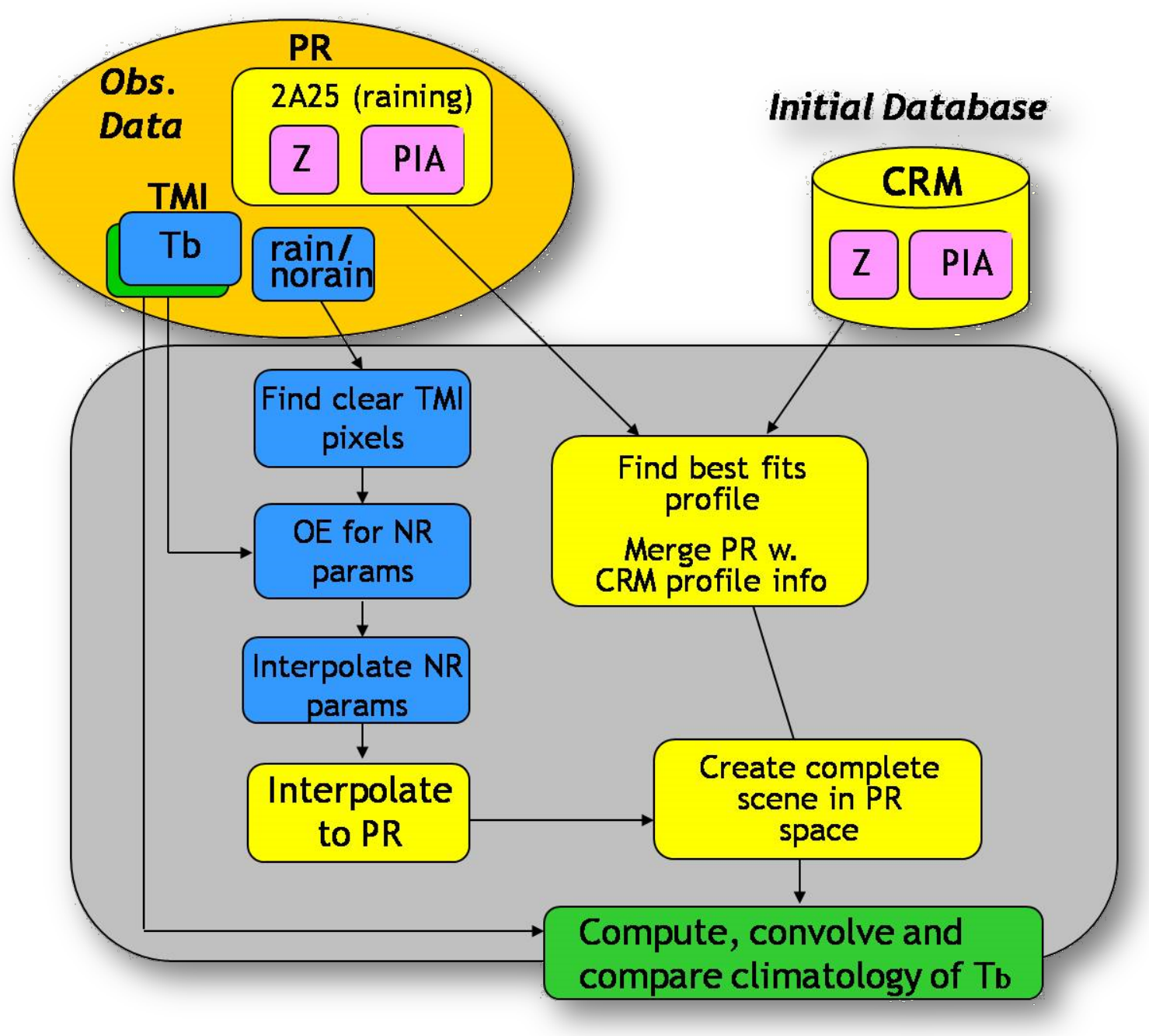
1) Generate DBs

$$Z = \frac{\lambda^5}{\pi^5 |K|^2} \int_D \sigma_b(D) N(D) dD$$

$$PIA = 20\tau_{ext}(0,\infty)\log e$$







Obs. Data

PR: 2A25 (raining) – Z, PIA

TMI: Tb, rain/norain

Initial Database

CRM: Z, PIA

Find clear TMI pixels

OE for NR params

Interpolate NR params

Interpolate to PR

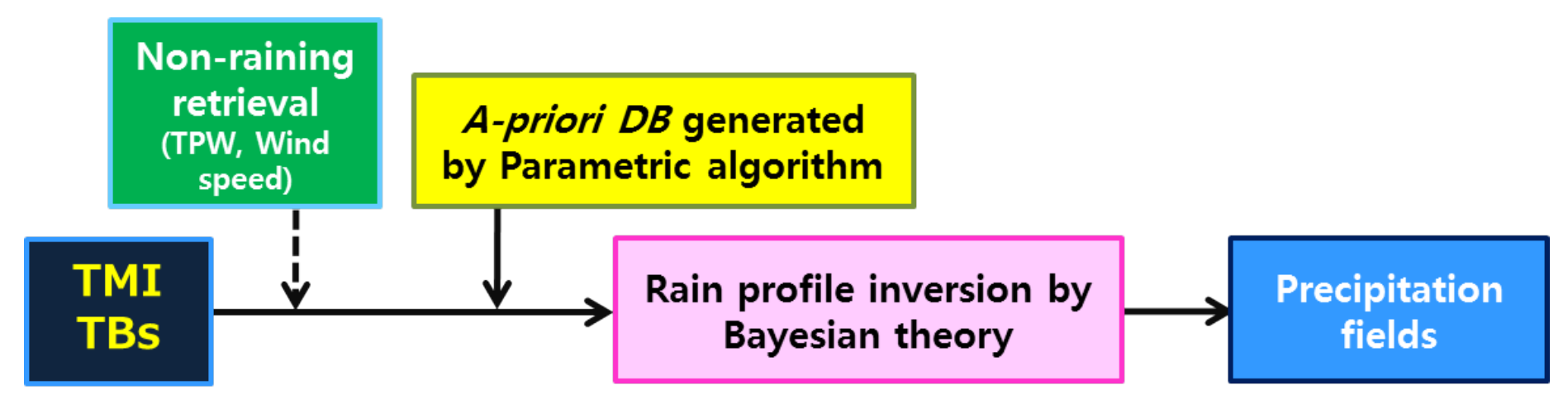
Find best fits profile

Merge PR w. CRM profile info

Create complete scene in PR space

Compute, convolve and compare climatology of Tb

2) Inversion by Bayesian theory



Non-raining retrieval (TPW, Wind speed)

A-priori DB generated by Parametric algorithm

TMI TBs

Rain profile inversion by Bayesian theory

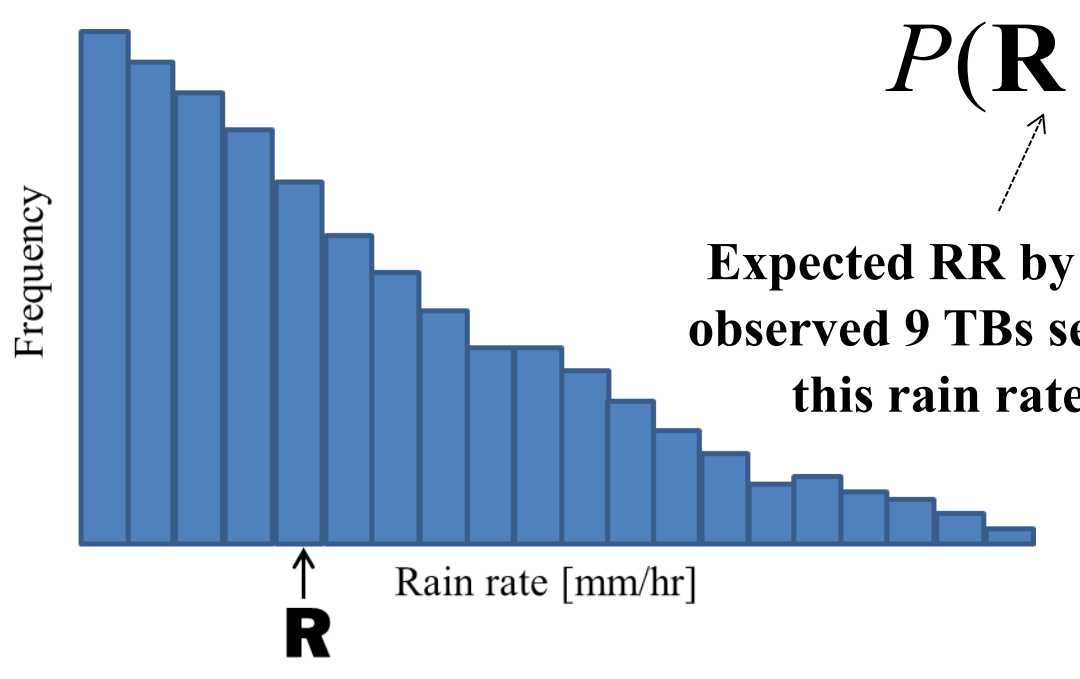
Precipitation fields

$$P(\mathbf{R}\,|\,\mathbf{T}_b) \propto P(\mathbf{R}) \times P(\mathbf{T}_b\,|\,\mathbf{R})$$

Expected RR by this observed 9 TBs set for this rain rate

Probability of this rain rate occurrence

Inversely weighted by differences of observed and simulated 9 TBs for each profiles



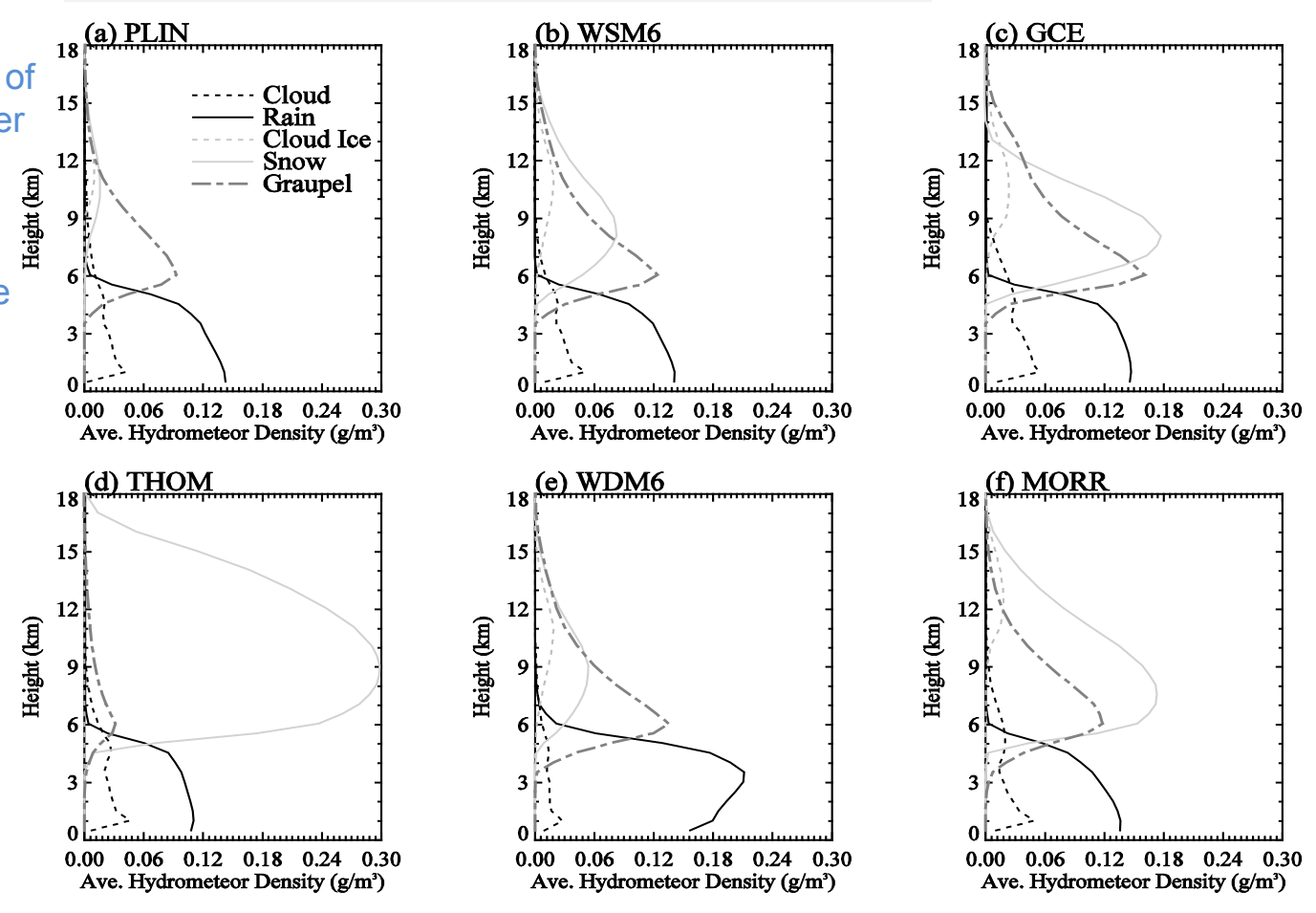
To overcome the dependency on the CRM, the **'Parametric rainfall algorithm'** was developed.

The **key of this methodology** is generating a-priori rainfall DB using TRMM PR observation, it is the **PR constrained DB**.

- Shin and Kummerow (2003)
- Masunaga and Kummerow (2005)
- Elsaesser and Kummerow (2008)
- Kummerow et al. (2011)

4. Part I: Impact of a-priori DBs using six WRF microphysics schemes

Vertical distribution of time- and area- averaged hydrometeors from six simulations



- Similar distribution of rain and cloud water compare to the WSM6
- Reduction of snow near and above the melting layer

- More cloud and rain water and more ice particle than the WSM6

- Too much snow
- Relatively less rain water

- Increased rain water below 5 km altitude
- Similar distribution of ice particle compare to the WSM6

Six cloud microphysics in WRF model

Single M Bulk	PLIN	Lin et al. 1983 Chen and Sun 20021	qv, qc, qi, qr, qs, qg	
	WSM6	Hong et al. 2004 Hong and Lim 2006		
	GCE	Tao and Simpson 1993 Lang et al. 2007		
Double M Bulk	THOM	Reisner et al. 1998 Thompson et al. 2004, 2008	qv, qc, qi, qr, qs, qg	Nci, Nsi
	WDM6	Lim and Hong 2010		Ncw, Nrw, N_{CCN}
	MORR	Reisner et al. 1998 Morrison et al. 2005		Ncw, Nci, Ncr, Ncs

Single moment schemes have differences in their cold rain processes (ice initiation, sedimentation property of solid particles).

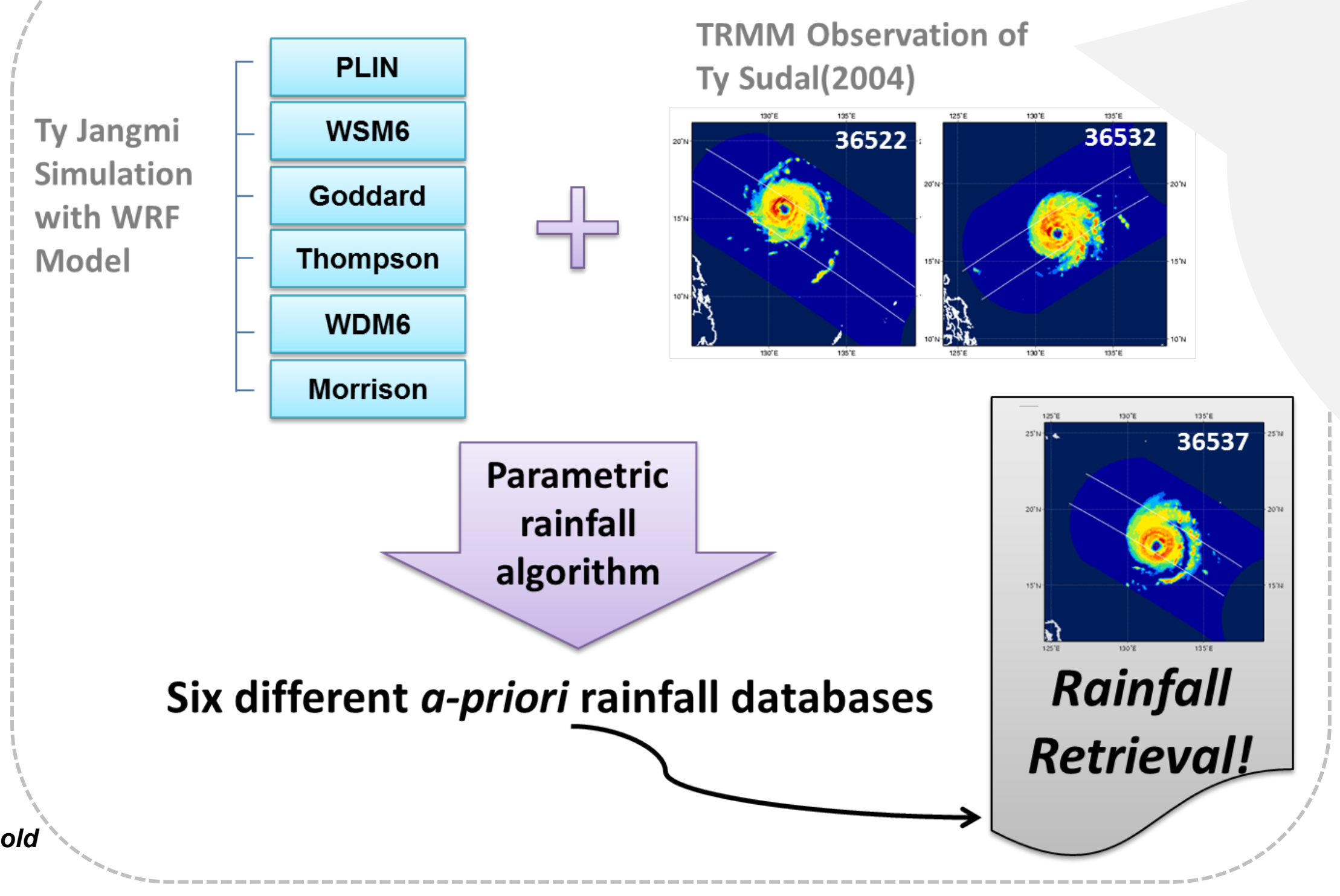
Double M for

Cold rain

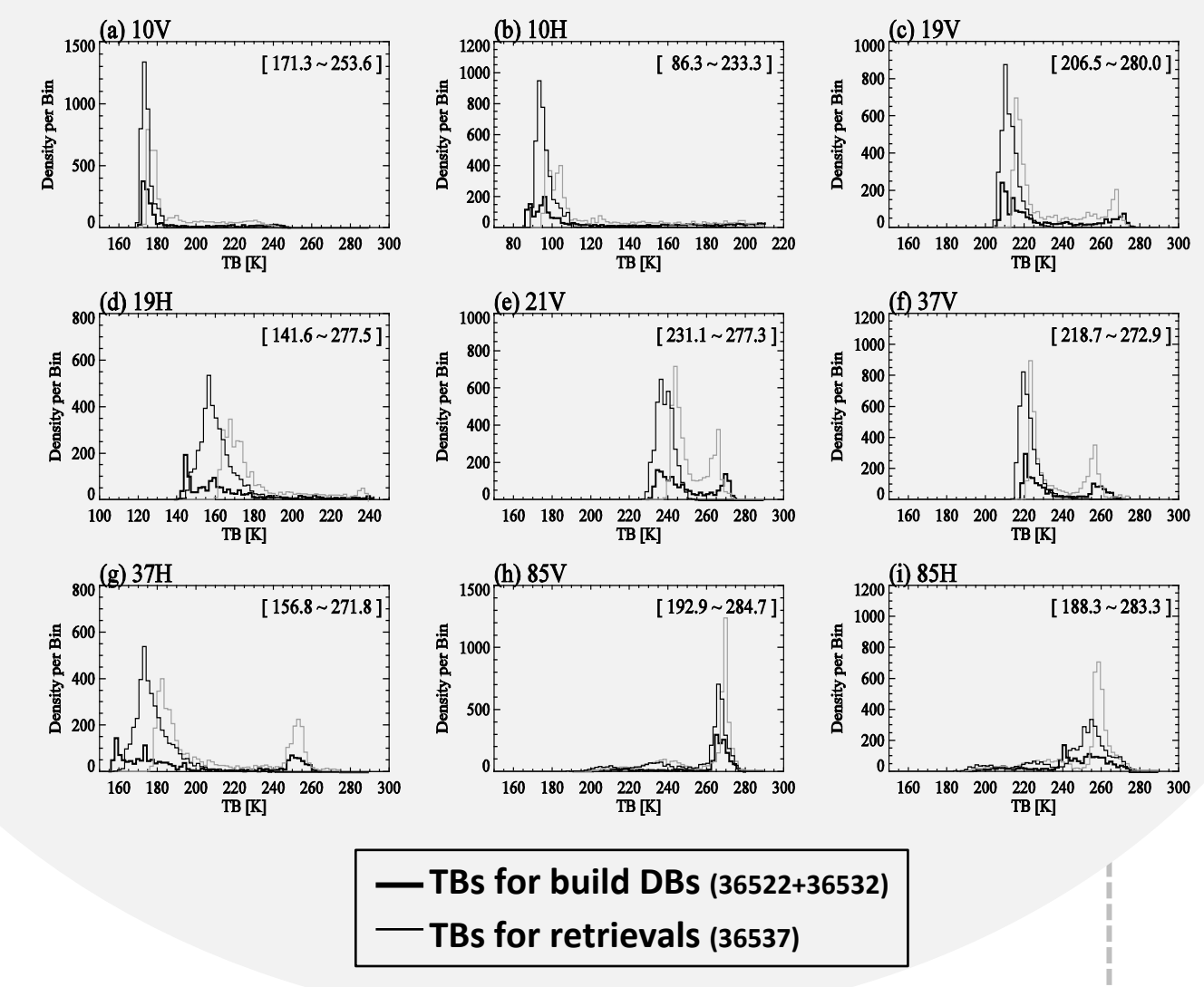
Warm rain

Warm rain , Cold rain

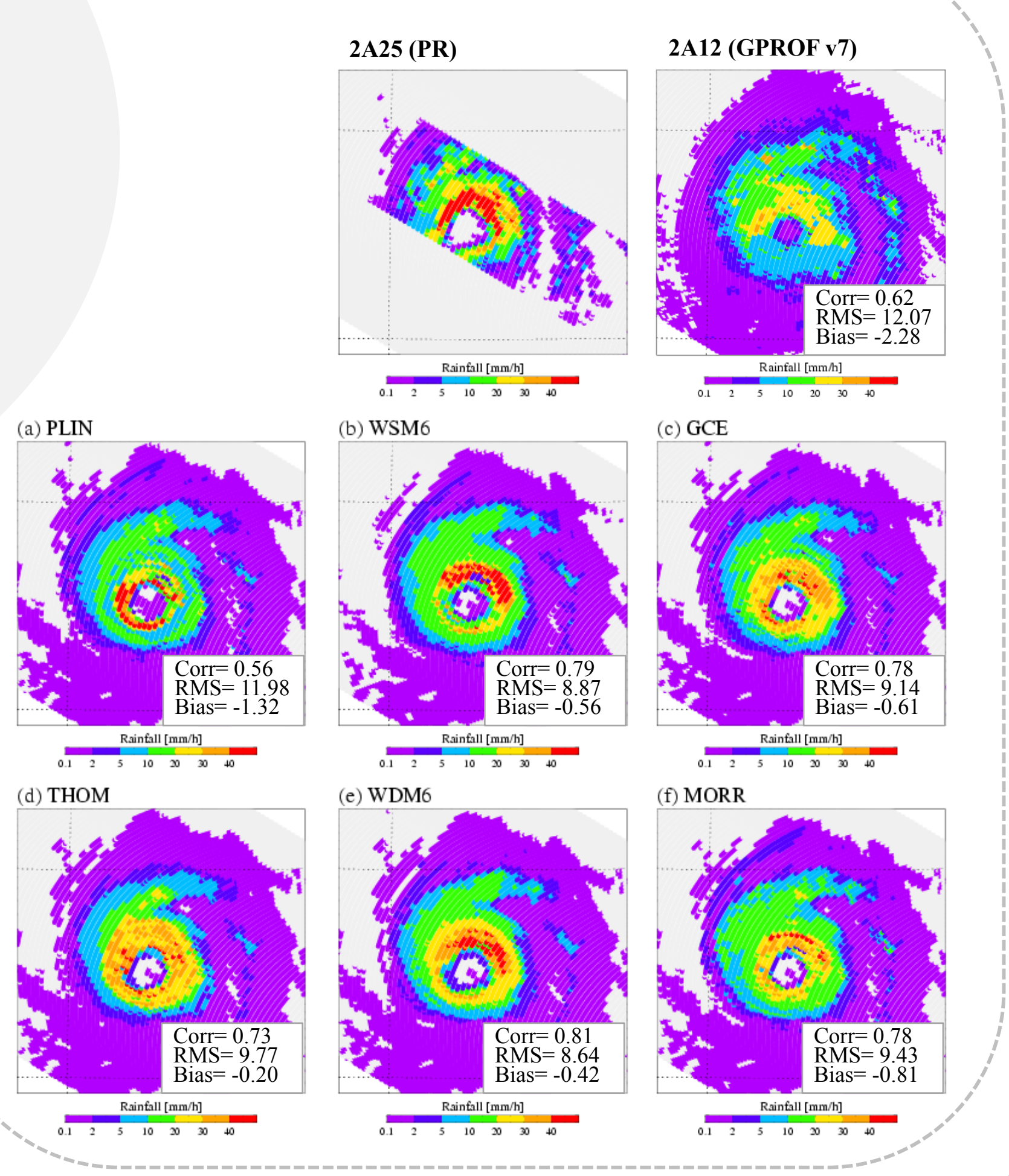
Experimental Design



Distribution of observed TBs for databases and retrieval target



Rainfall retrieval results



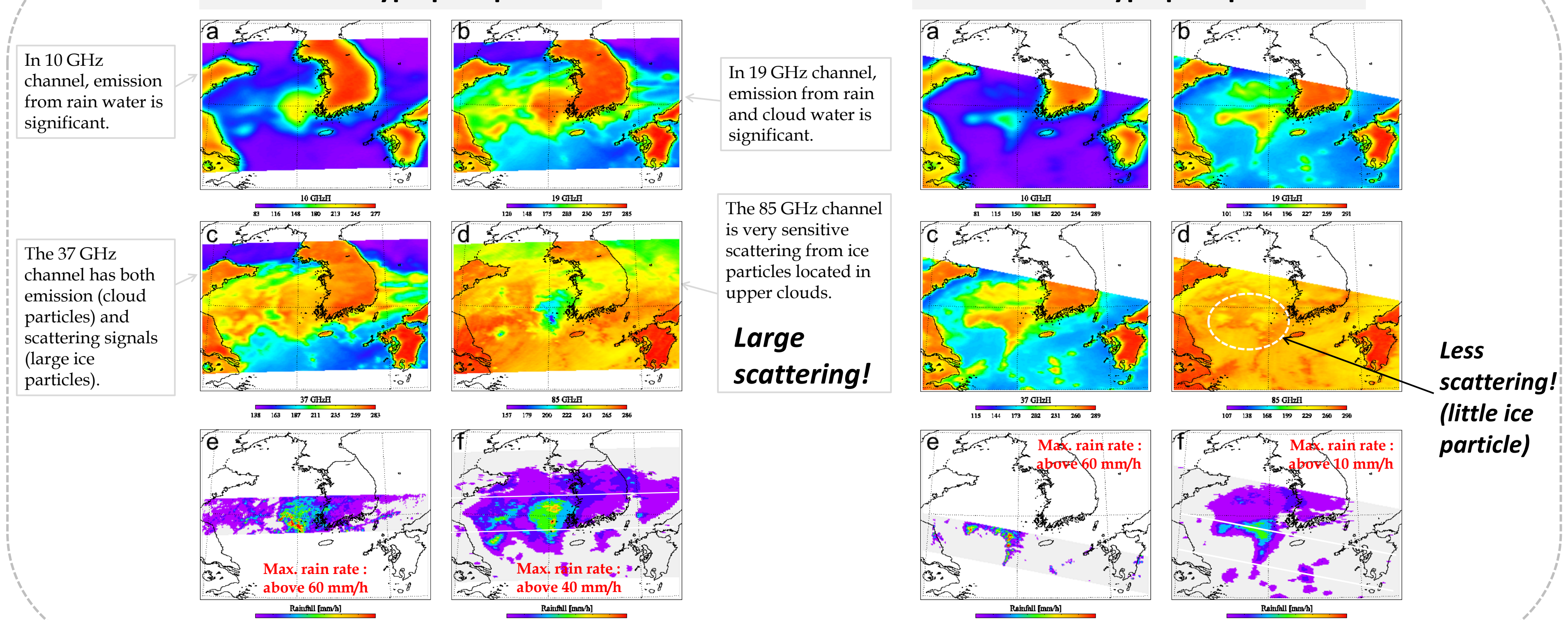
As expected, the characteristics of the *a-priori* databases are inherited from the individual cloud microphysics schemes. Major results show that convective rainfall regions are not well captured by the LIN and THOM schemes-based retrievals. Rainfall distributions and their quantities retrieved from the WSM6 and WDM6 schemes-based estimations, however, show relatively better agreement with the PR observations.

Kim, J.-H., D.-B., Shin, and C. D. Kummerow, 2013: Impacts of a-priori databases using six WRF microphysics schemes on passive microwave rainfall retrievals. *J. Atmos. Oceanic Technol.*, **30**, 2367–2381.

5. Part II: Two heavy rainfall cases with different cloud microphysics

This study includes the discrepancy of estimated rain rate from passive radiometer and active radar for two rainfall systems of different cloud microphysics near the Yellow Sea. The first case have high cloud top (HCT, cold type) with large ice particles and the other case is precipitation with mid cloud top (MCT, warm type) having less ice particles.

TRMM observations for two rainfall cases



In 10 GHz channel, emission from rain water is significant.

The 37 GHz channel has both emission (cloud particles) and scattering signals (large ice particles).

In 19 GHz channel, emission from rain and cloud water is significant.

The 85 GHz channel is very sensitive scattering from ice particles located in upper clouds.

Large scattering!

Less scattering! (little ice particle)

Sensitivity experiment by various a priori DBs

ex) 4W_2004MJJAS — Simulated component (4W), Observed component (2004MJJAS)

		Simulated component		
		4 WRF CRMs	5 WRF CRMs	9 GPROF CRMs
Observed component	2004 MJJAS	4W_2004MJJAS	5W_2004MJJAS	9G_2004MJJAS
	2004 JJA	4W_2004JJA	5W_2004JJA	9G_2004JJA
	2005 JJA	4W_2005JJA	5W_2005JJA	9G_2005JJA
	2004 JJA, 2005 JJA	4W_0405JJA	5W_0405JJA	9G_0405JJA
	2004 MJJAS, 2005 JJA	4W_0405mJJAs	5W_0405mJJAs	9G_0405mJJAs

	Corr	Bias	RMS
(a) 4W_2004MJJAS	0.76	0.67	3.72
(b) 5W_2004MJJAS	0.75	0.60	3.75
(c) 9G_2004MJJAS	0.72	0.73	3.88
(d) 4W_2004JJA	0.79	0.36	2.77
(e) 5W_2004JJA	0.77	0.27	2.61
(f) 9G_2004JJA	0.77	0.49	3.07
(g) 4W_2005JJA	0.63	0.51	4.28
(h) 5W_2005JJA	0.65	0.48	4.02
(i) 9G_2005JJA	0.61	0.53	4.45
(j) 4W_0405JJA	0.75	0.44	3.25
(k) 5W_0405JJA	0.72	0.43	3.28
(l) 9G_0405JJA	0.70	0.79	4.55
(m) 4W_0405mJJAs	0.73	0.74	4.10
(n)4W_0405mJJAs	0.73	0.75	4.10
(o) 9G_0405mJJAs	0.68	1.00	5.16

	Corr	Bias	RMS
(a) 4W_2004MJJAS	0.61	-0.18	2.23
(b) 5W_2004MJJAS	0.61	-0.19	2.25
(c) 9G_2004MJJAS	0.57	-0.18	2.25
(d) 4W_2004JJA	0.66	-0.17	2.14
(e) 5W_2004JJA	0.65	-0.18	2.16
(f) 9G_2004JJA	0.63	-0.19	2.19
(g) 4W_2005JJA	0.65	-0.03	1.94
(h) 5W_2005JJA	0.66	-0.06	1.94
(i) 9G_2005JJA	0.65	-0.04	1.94
(j) 4W_0405JJA	0.66	-0.16	2.09
(k) 5W_0405JJA	0.64	-0.16	2.09
(l) 9G_0405JJA	0.64	-0.15	2.08
(m) 4W_0405mJJAs	0.61	-0.18	2.22
(n)4W_0405mJJAs	0.60	-0.19	2.25
(o) 9G_0405mJJAs	0.57	-0.17	2.23

Findings and concluding remarks

- The dependency of CRM and its microphysics is significant in rainfall estimation from deep convective cloud, because this system has ice particles in the upper atmosphere which brings a scattering signal at high frequency channels. On the other hand, high resolution TBs of 85 GHz (7 km x 5 km) channel gives little knowledge in warm type precipitation case and it brings underestimation of rain rate.
- In GPM era, a network of microwave radiometers to provide the best possible global coverage and sampling including high latitude regions, where complicate microphysics is revealed. I hope this research could contribute to improve accuracy of microwave rainfall measurements for various cloud and precipitation systems by understanding the role of microphysics in CRMs in microwave rainfall estimation.

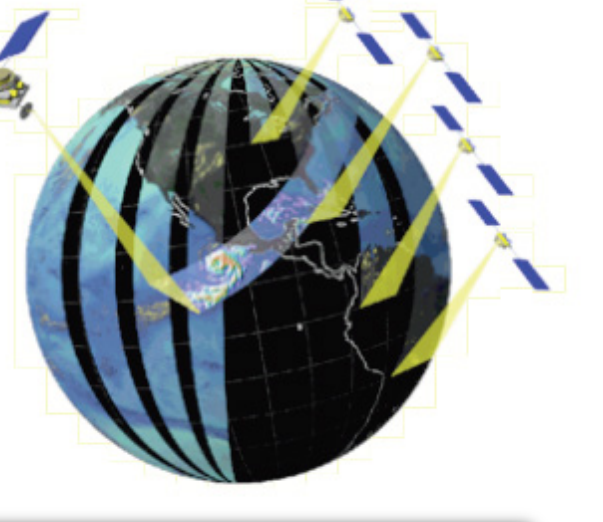


Image Credit: NASA/Bill Ingalls

To better understand Earth's weather and climate cycles, the GPM Core Observatory will collect information that unifies and improves data from an international constellation of existing and future satellites by mapping global precipitation every three hours.

Fri, 2014-03-20 9:41 a.m. EDT
The Global Precipitation Measurement mission's Core Observatory is performing normally. Both the GPM Microwave Imager and Dual-frequency Precipitation Radar are collecting science data.

Thu, 2014-02-27 1:38 p.m. EST
Liftoff! The GPM Core Observatory launched on Feb. 27 2014 (above).

19th International TOVS working group Study Conferences | 26 March- 1 April 2014, JeJu, Korea