Outline of 5 Lectures

(A Satellite-based Tropical Cyclone Module)

1. Sept. 17, 2008: TC best track definition and datasets, global distribution of TCs; Review of history of meteorological satellites, introducing different orbits, scanning patterns, and space-time samplings. Also introduce the differences between the satellites and the instruments.

2. Sept. 19, 2008: Introduction of space borne instruments including visible, IR and microwave. Will briefly talk about radiative transfer theories in different channels and rainfall retrieval algorithms from IR and microwave.

Problem set: Due on the Oct. 6, 2008

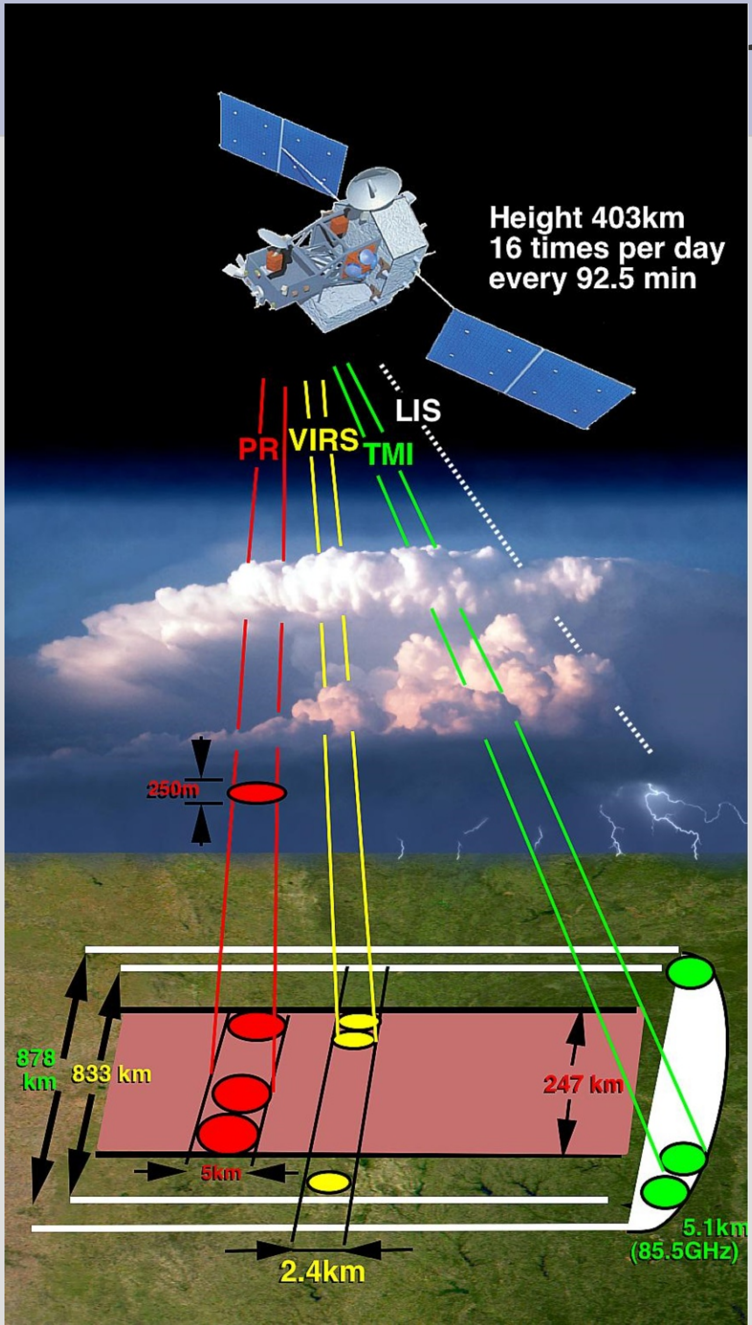
3. Oct . 10, 2008: Homework presentation. Climatology of tropical cyclone rainfall and its contribution to global precipitation.

4. Nov. 19, 2008: SeaWinds & SFMR sea surface wind retrieval; Current status of TC intensity and rainfall forecasts. Introduction of satellite-based TC intensity and rainfall prediction techniques, including DVORAK, SHIPS, and R-CLIPER.

5. Nov. 21, 2008: **Convective properties of tropical cyclones: an introduction of UU TRMM TCPF database and its application on TC intensification study.**

Problem set: Due on the Dec. 5, 2008

Motivation of Building TRMM PF Database

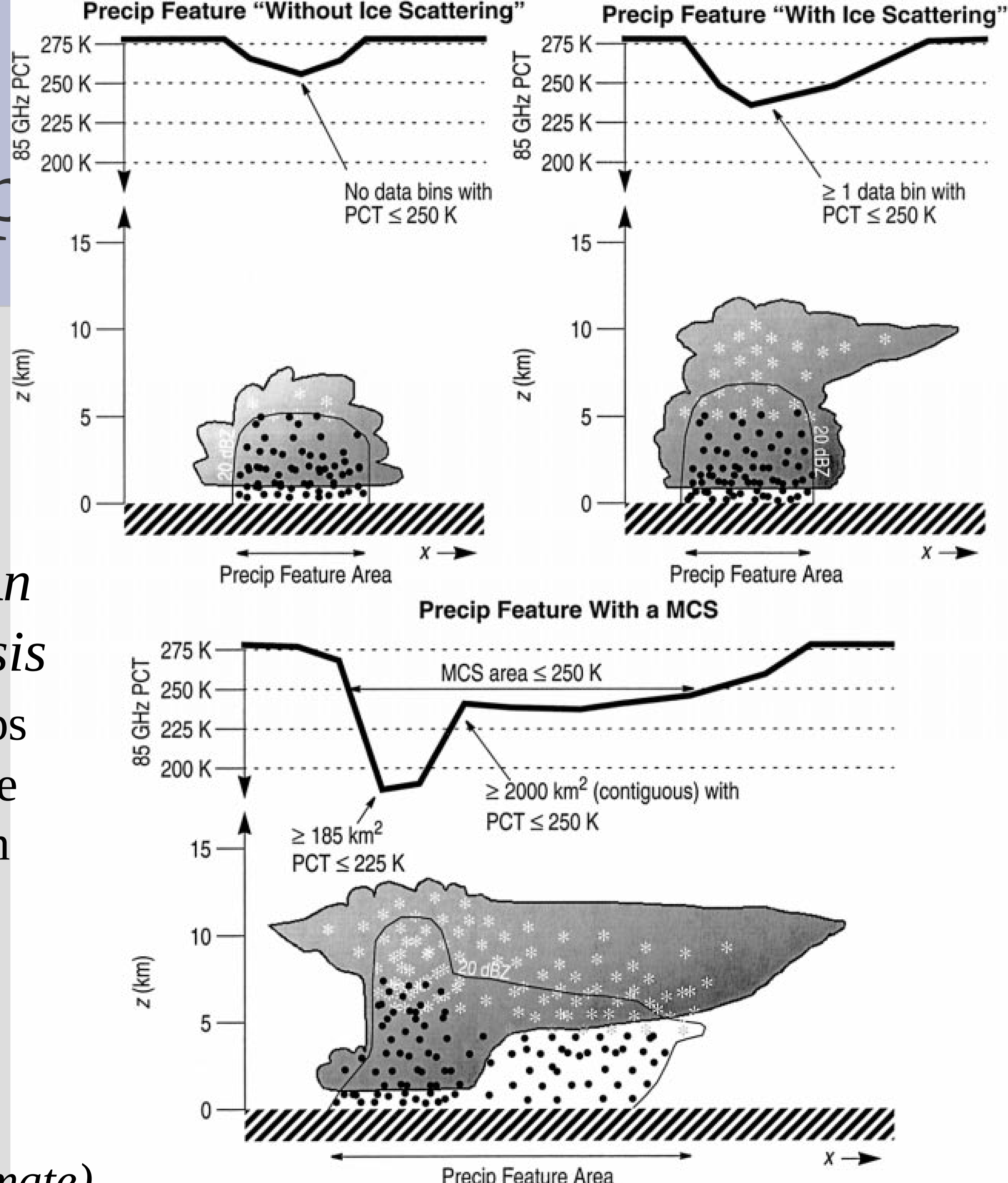


NASA TRMM : PR, TMI, VIRS, and LIS

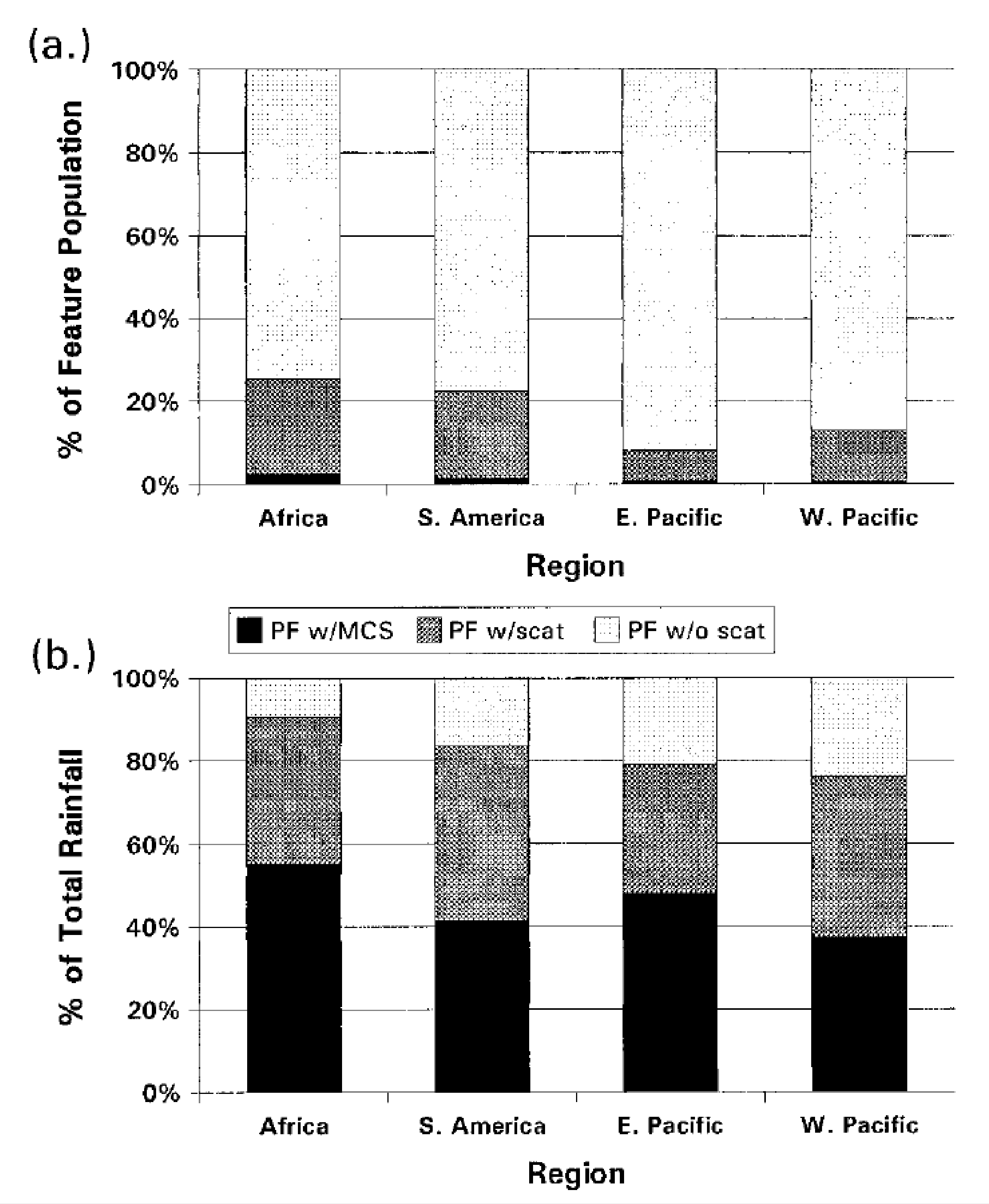
- TRMM has 10 years of data (huge amount) from different sensors
- Traditional pixel-based or grid-based analysis methods are not efficient
- Event-based analysis method: summarize observations from individual precipitation events

“Precip

Concept of Precipitation Feature (PF): *An event-based analysis method*, which groups the pixels with satellite measured properties in certain criteria.



Nesbitt et al. 2000 (J of Climate)



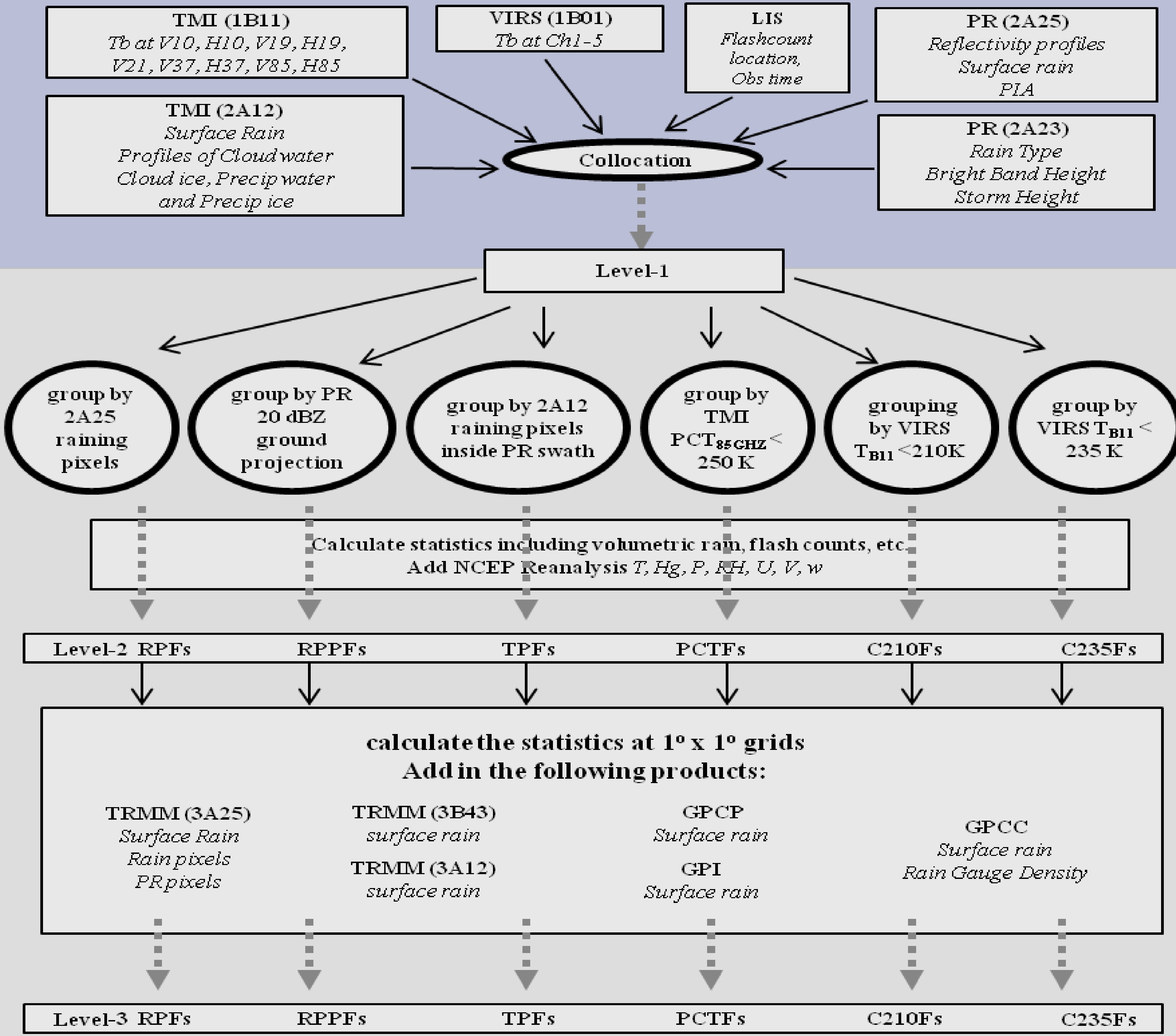
Contribution by each feature category to total feature population and total regional rainfall.

3 Steps in Building the TRMM PF Database

1. Collocation → pixel-level data : Level 1

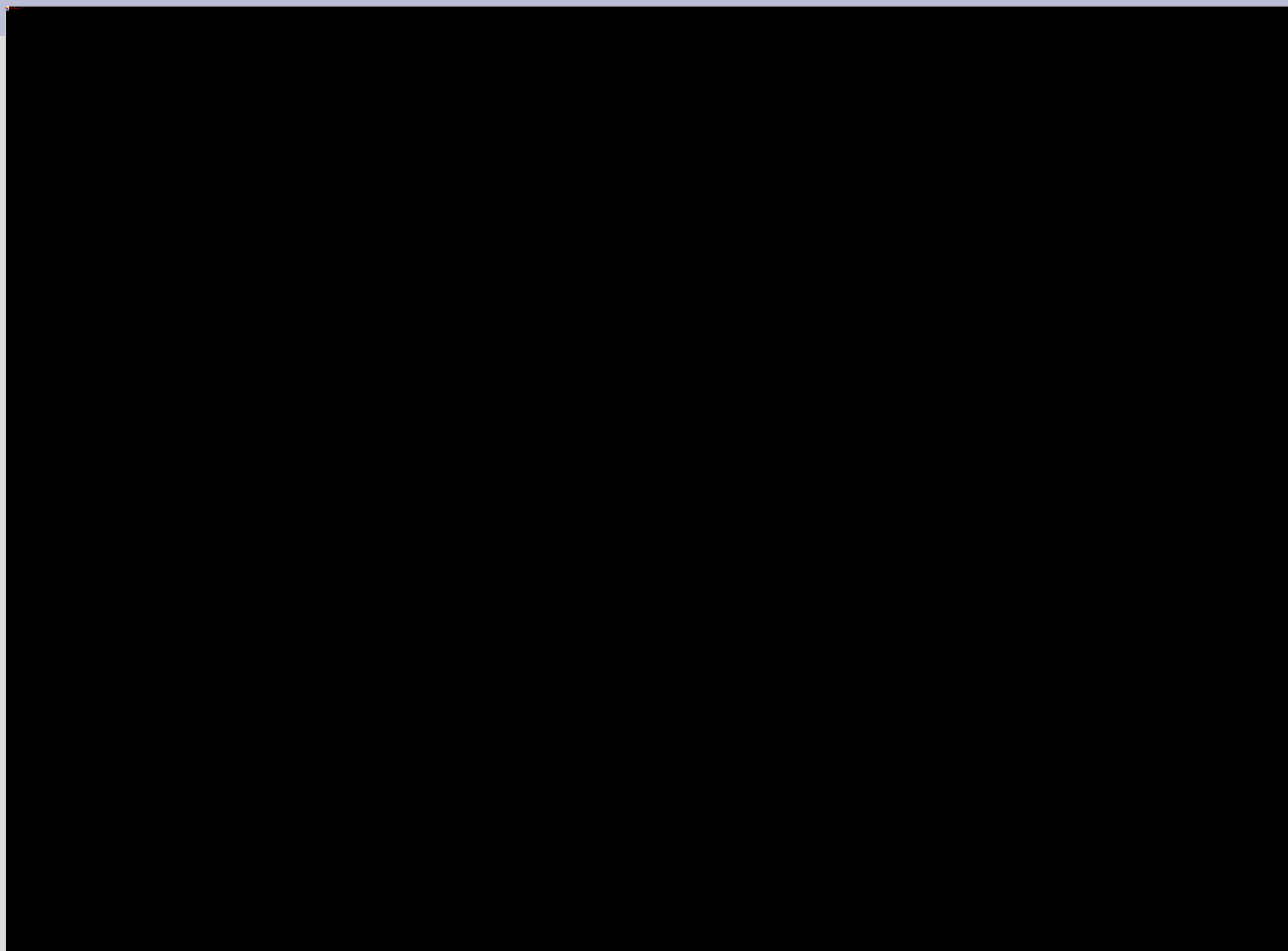
2. PFs are defined with different criteria using the collocated data → feature-level: Level 2

3. Generating statistics→ grid-level: Level 3


TMI (1B11)
Tb at V10, H10, V19, H19, V21, V37, H37, V85, H85
VIRS (1B01)
Tb at Ch1-5
LIS
Flashcount location, Obs time
PR (2A25)
Reflectivity profiles
Surface rain
PIA
TMI (2A12)
Surface Rain
Profiles of Cloud water
Cloud ice, Precip water
and Precip ice
Collocation
PR (2A23)
Rain Type
Bright Band Height
Storm Height
Level-1
group by 2A25 raining pixels
group by PR 20 dBZ ground projection
group by 2A12 raining pixels inside PR swath
group by TMI PCT85GHZ < 250 K
grouping by VIRS TB11 <210K
group by VIRS TB11 < 235 K
Calculate statistics including volumetric rain, flash counts, etc.
Add NCEP Reanalysis T, Hg, P, RH, U, V, w
Level-2 RPFs
RPPFs
TPFs
PCTFs
C210Fs
C235Fs
calculate the statistics at 1° x 1° grids
Add in the following products:
TRMM (3A25)
Surface Rain
Rain pixels
PR pixels
TRMM (3B43)
surface rain
TRMM (3A12)
surface rain
GPCP
Surface rain
GPI
Surface rain
GPCC
Surface rain
Rain Gauge Density
Level-3 RPFs
RPPFs
TPFs
PCTFs
C210Fs
C235Fs

Acronyms	Definition	Criteria	Population (million)
RPF	Radar Precipitation Feature	Pixels with 2A25 rainfall rate >0	78.2
RPPF	Radar Projection Precipitation Feature	Pixels with 20 dBZ anywhere above ground	68.6
TPF	TMI Precipitation Feature	Pixels with 2A12 rainfall rate > 0	14.8
PCTF	TMI cold 85 GHZ PCT Feature	Pixels with 85 GHZ PCT < 250 K	6.2
C210F	Cloud Features with 210 K	VIRS T_{B11} < 210 K	2.8
C235F	Cloud features with 235 K	VIRS T_{B11} < 235 K	20.5
C273F	Cloud features with 273 K	VIRS T_{B11} < 273 K	77.2

Demonstration of the feature types using a severe hail storm case (Zipser et al., 2006).



Level 1 Parameters

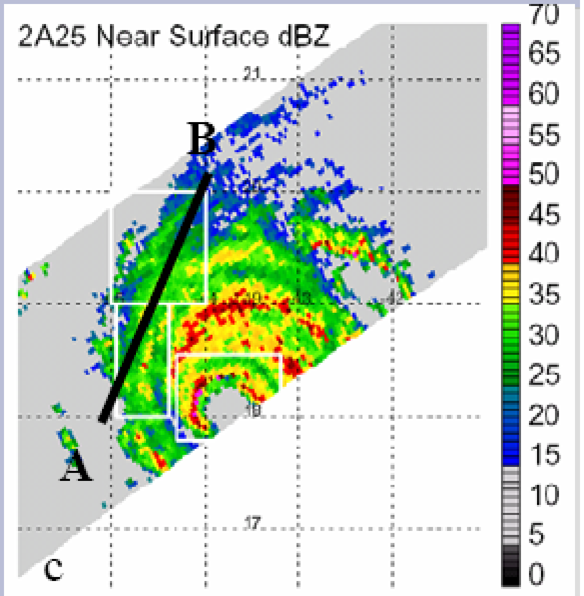
1. General: orbit number, time, lat, lon, etc.

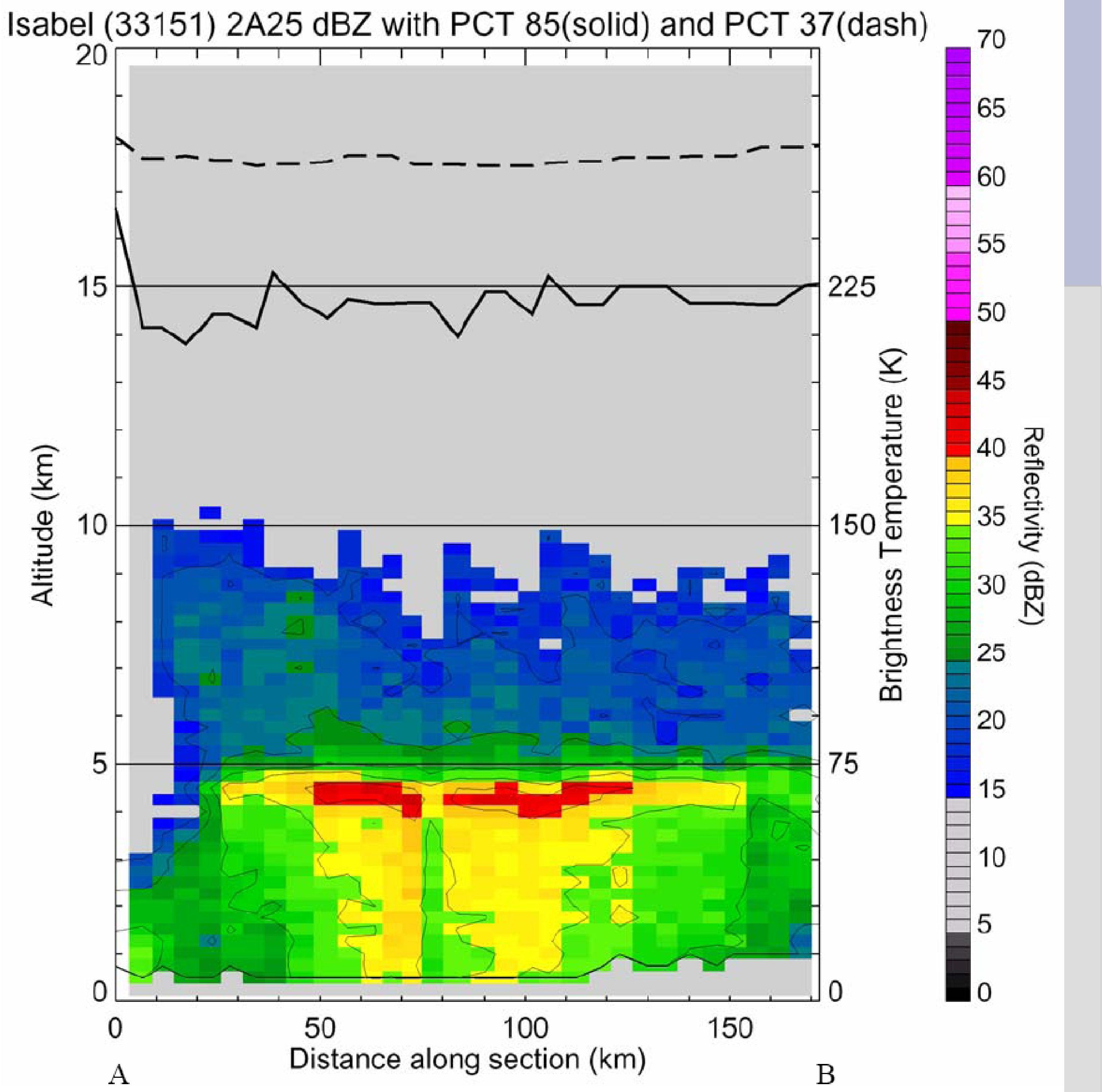
2. From PR: dBZ profile, rain_2A25 profile

3. From TMI: TBs, rain_2A12, LWC_2A12, IWC_2A12

4. From LIS: flash count, flash rate

5. From VIRS: TBs from Channel 1-5


2A25 Near Surface dBZ
B
A
c
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0


Isabel (33151) 2A25 dBZ with PCT 85(solid) and PCT 37(dash)
Altitude (km)
Distance along section (km)
Brightness Temperature (K)
Reflectivity (dBZ)
A
B
20
15
10
5
0
50
100
150
225
75

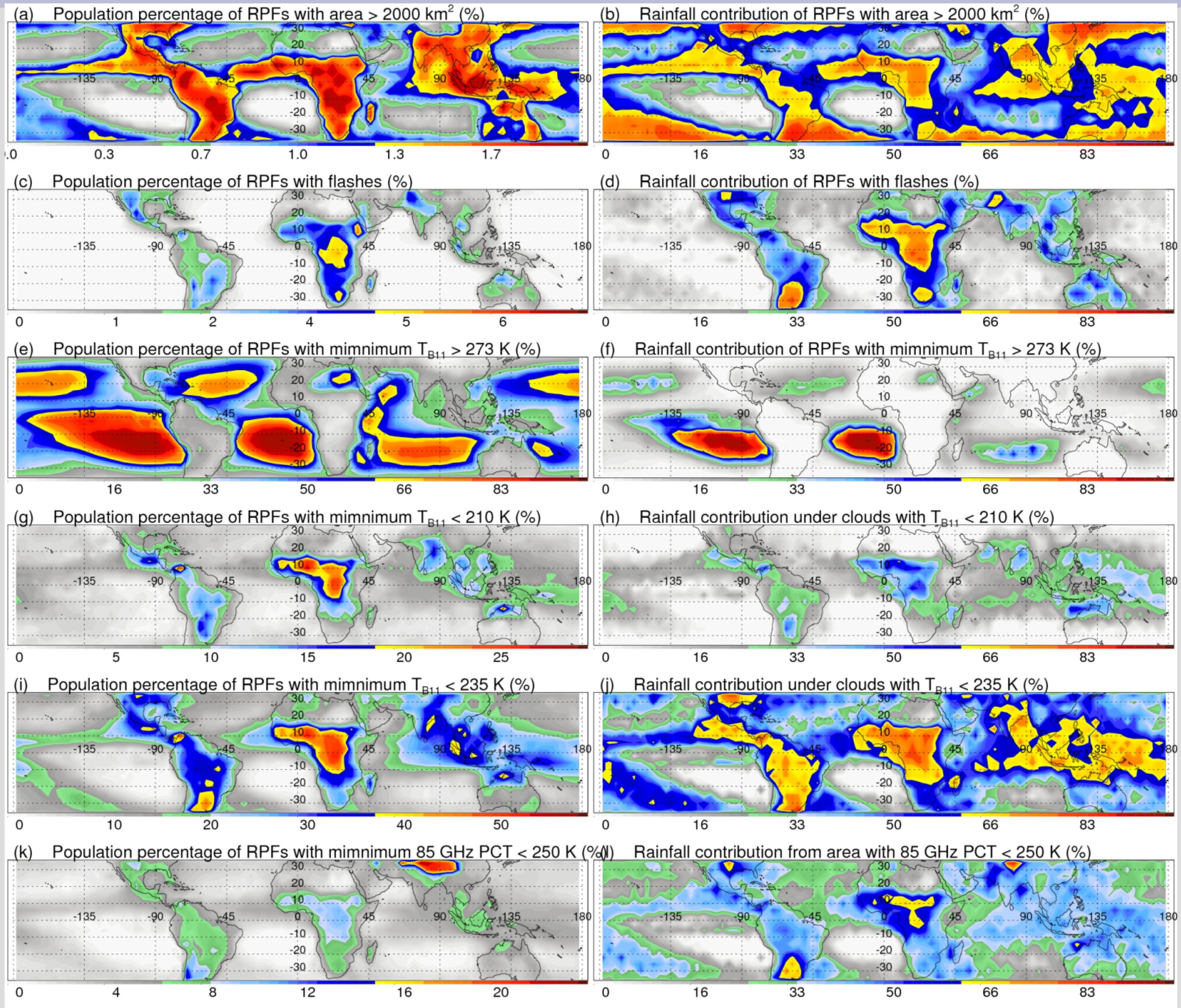
Level 2 Parameters

1. General: orbit #, grp #, time, PF center_lat & lon
2. From PR: Maxnsz, Max6km, Max9km, Max20dbz, Max40dbz, Maxdbz profile, Volrain, Volrain_20db, Nmcs, Rainmcs, Npixels, Nmcs, so on and so forth.
3. From TMI: Npixel2a12, Min85pct, Min37pct , Volrain_2a12, rainmcs_2a12, etc.
4. From LIS: flash count, flash_total
5. From VIRS:Nch4le210 , 235, 273(#of PR pixels with Tb11<=210), Median value of Tbs
6. From NCEP reanalysis: T, u, v, w, Rh, etc.

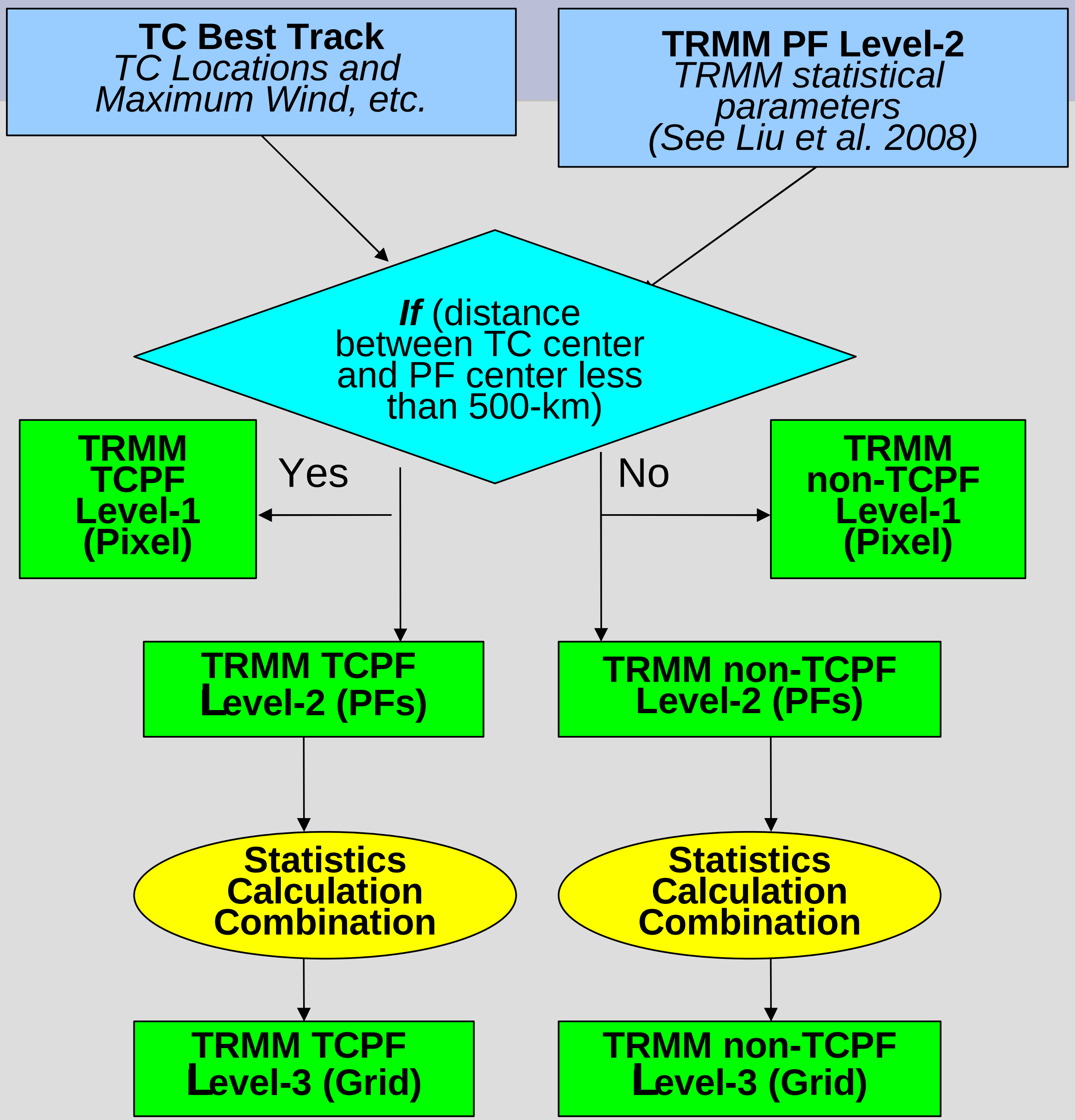
Level 3 Parameters

Monthly mean, max, or total of previous parameters .

Dimesion:[80, 360, 8]



Tropical Cyclone Related PF (TCPF) Database



Number of TCs and TCPFs for each basin and each year during 1998-2006

		ATL	EPA	NWP	NIO	SIO	SPA	**Total**
TCs	1998	14	13	19	8	15	21	**90**
	1999	12	9	23	5	20	12	**81**
	2000	15	19	25	4	17	9	**89**
	2001	15	15	29	3	14	7	**83**
	2002	12	15	24	4	17	8	**80**
	2003	16	16	23	3	18	10	**86**
	2004	15	12	31	5	16	5	**84**
	2005	28	15	24	6	18	8	**99**
	2006	10	19	21	6	15	8	**79**
	Total	**137**	**133**	**219**	**44**	**150**	**88**	**771**
TCPFs	1998	4202	1869	4824	1252	4482	4344	**20973**
	1999	3953	1455	5465	868	3975	1976	**17592**
	2000	3467	2565	6760	690	4354	1827	**19663**
	2001	4182	1740	7416	331	3595	1473	**18737**
	2002	4116	2881	7118	336	4085	1070	**19606**
	2003	5118	2122	7425	772	5750	1978	**23165**
	2004	5231	1617	9591	970	4371	740	**22520**
	2005	8023	1990	7125	1217	3299	1482	**23136**
	2006	2268	2935	5951	825	2820	1500	**16299**
	Total	**40560**	**19174**	**61675**	**7261**	**37037**	**16628**	**182335**

Table 1: Characteristics of TRMM TCPFs and non-TCPFs

	TCPFs						Non-TCPFs					
	ATL	EPA	NWP	NIO	SIO	SPA	ATL	EPA	NWP	NIO	SIO	SPA
Mean PF Size	1447	1494	2018	1510	1559	2267	624	740	758	799	672	779
Mean 2A25 Volumetric Rain (km^2 mm/hr)	5,714	5,258	8,495	5,749	5,806	8,439	1,880	2,226	2,137	2,426	1,927	2,143
Mean 2A12 Volumetric Rain (km^2 mm/hr)	4,984	5,138	7,945	5,394	5,749	8,487	1,653	2,251	1,879	2,045	1,725	1,923
Mean Minimum 85 GHz PCT (K)	256	260	259	247	260	264	263	266	263	263	265	264
Mean Minimum 37 GHz PCT (K)	268	272	271	260	272	275	274	276	274	275	276	275
Mean Flash Count (#)	0.20	0.06	0.13	0.10	0.08	0.05	0.31	0.10	0.13	0.17	0.14	0.13
Mean Maximum 20 dBZ Height (km)	5.43	5.32	5.63	5.45	5.25	5.38	5.33	4.65	5.60	5.57	4.90	5.13
Mean Maximum Near Surface dBZ	33.0	31.5	32.3	32.9	31.8	31.5	33.4	32.2	32.5	33.6	32.5	32.1

An application of TCPF database on TC Intensity Change Study

Is tropical cyclone intensity change related to the strength of its convective precipitation features?

Using 9 years of TRMM data to search for an answer

Motivation

- SHIPS model does not have any parameter related to convective intensity. However, early studies suggest that hot towers (Simpson et al. 1998) and convective bursts (Steranka et al. 1986) near the eye can be related to tropical cyclone (TC) intensity change.
- Kelly et al. (2004, 2005) found that the chance of intensification increases when one or more hot towers exist in the TC's eyewall using TRMM PR and WSR-88D data for selected Atlantic TCs during 1998-2003 (for TRMM) and 1995-2005 (for WSR-88D).
- While the forecasting of TC intensity change has been quite difficult, the forecasting of rapid intensification (RI) has been particularly challenging.
- R. Rogers (2008 TRMM conference talk) found that TRMM PR reflectivity profiles decrease less (more) rapidly with height at high altitude for RI (non-RI) cases after a convective burst.

Objectives

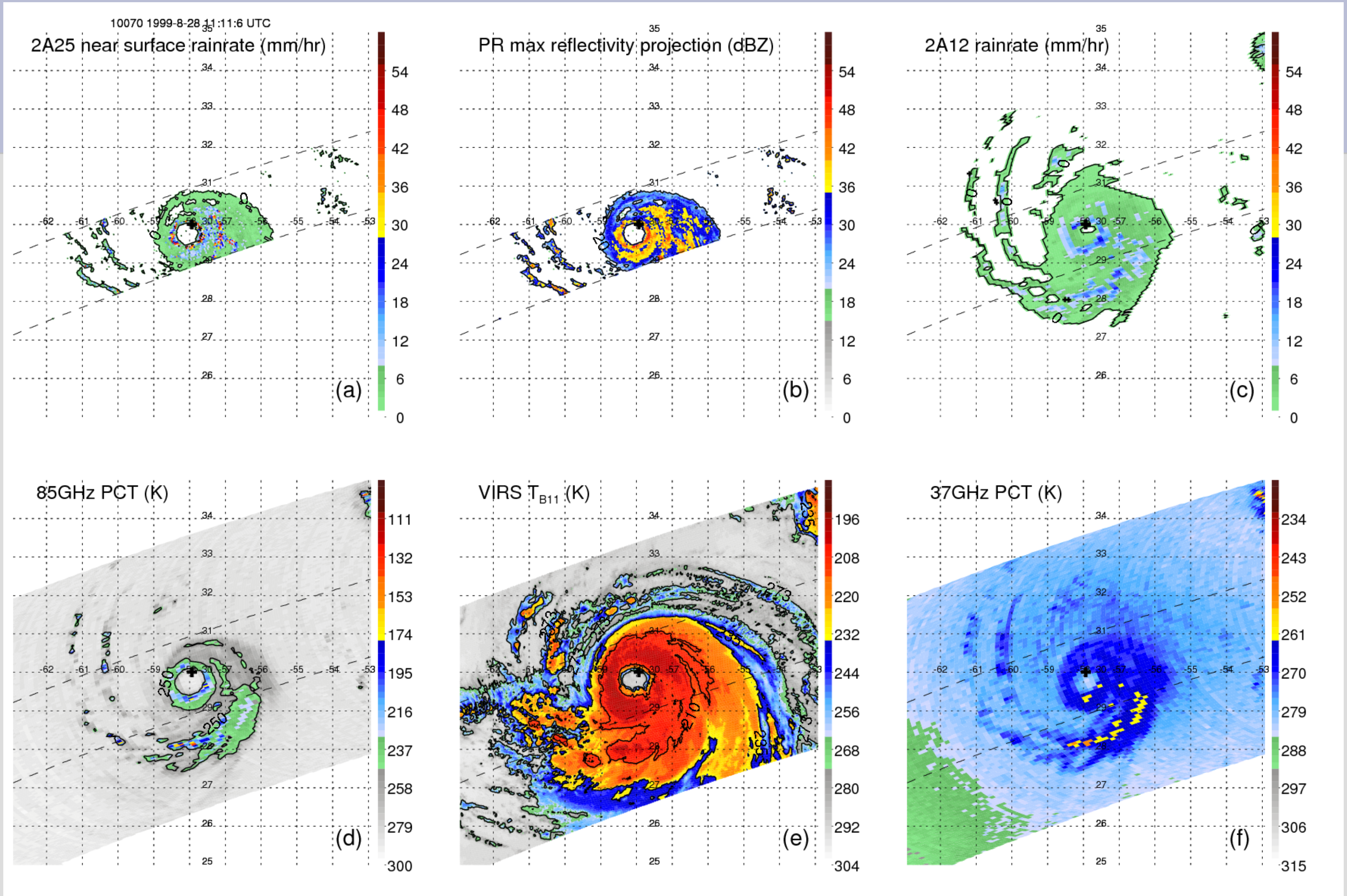
- Rank the strength of a TC's convective precipitation features in the eyewall (EW) stratified by the TC's intensity change:
  i.e., non-intensifying (NonIN) and intensifying (IN) including rapid intensifying (RI) and slow intensifying (SI) stages using a 9-yr (1998-2006) TRMM Precipitation Feature (PF) database.
- Evaluate the probability of RI/IN when the TC's strongest eyewall (EW) PF contains one or more hot towers.
- Compare environmental factors (SST, vertical wind shear, moisture) for IN (RI and SI), and NonIN cases.

Data and Methodology

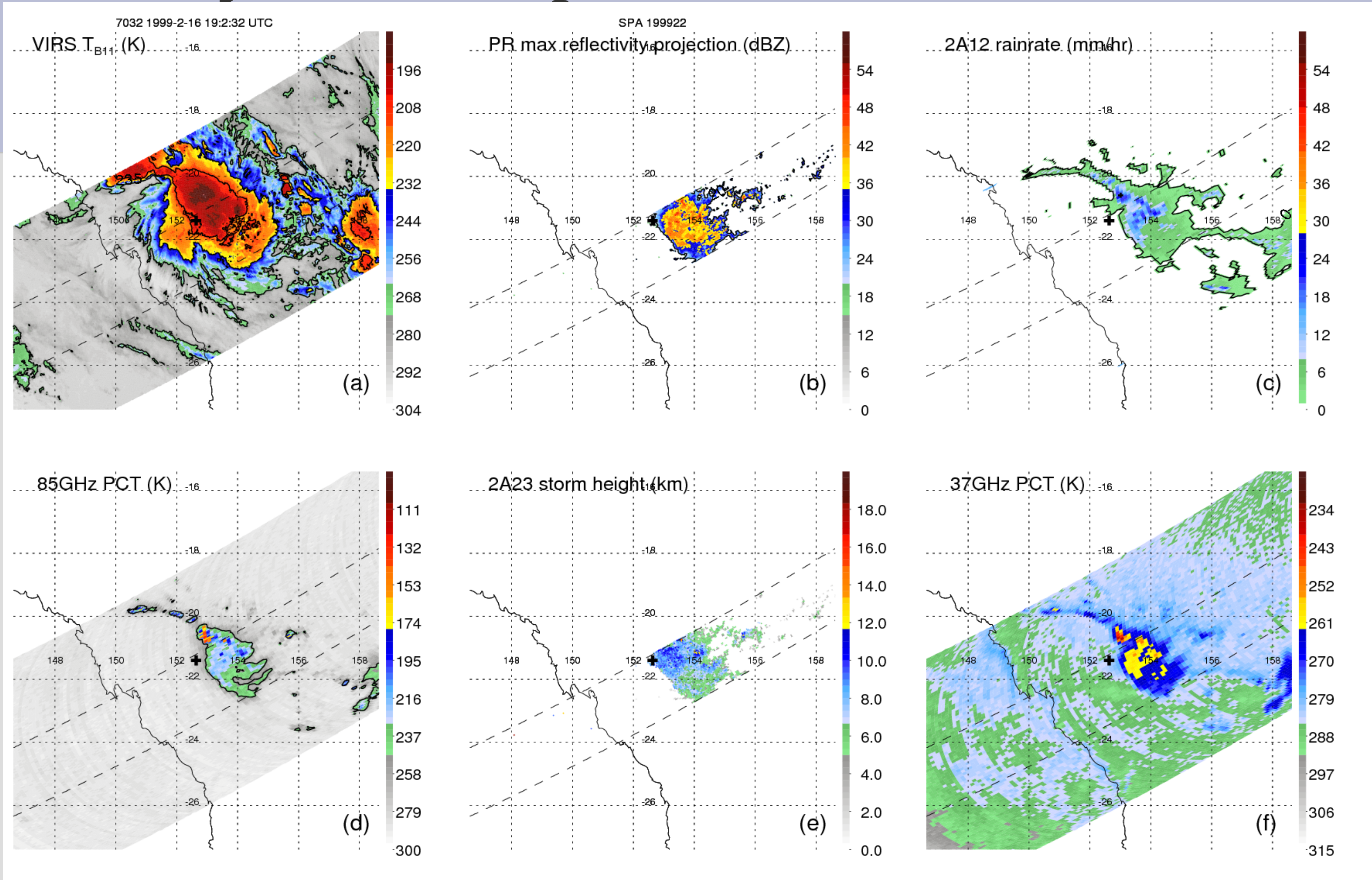
- Based on 9 years (1998-2006) of the UU TRMM Precipitation Feature (PF) database, Tropical Cyclone related PFs (TCPFs) are identified for over 700 TCs in six basins: Atlantic (ATL), East Pacific (EPA), Northwest Pacific (NWP), North Indian Ocean (NIO), South Indian Ocean (SIO), and South Pacific (SPA).
- Manually select TRMM orbits in which TC EW is well-observed. Then we select the strongest EW PF from each orbit. We have a total of 1054 such EW PFs to be analyzed.

	N=EWPFs	N=storms	ATL	EPA	NWP	NIO	SIO	SPA
RI	44	39	5	8	12	1	12	6
SI	515	221	114	57	181	29	98	36
IN	559	227	119	65	193	30	110	42
NonIN	495	191	143	73	130	25	89	35
Total	1054	255	262	138	323	55	199	77

Accepted Example: TRMM Observations of Hurricane Cindy (1999)



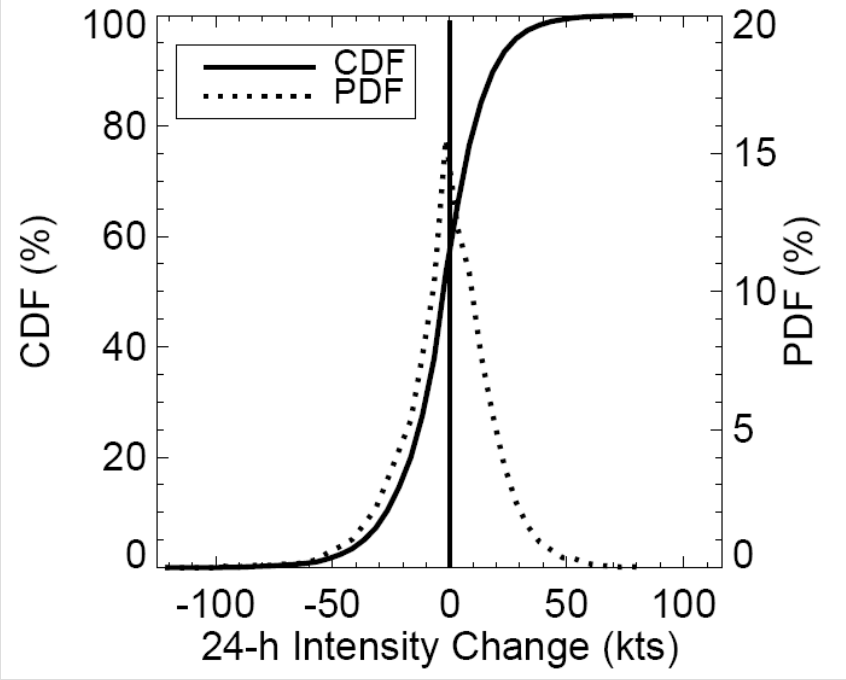
Rejected Example: SPA TC ID# 1999-22



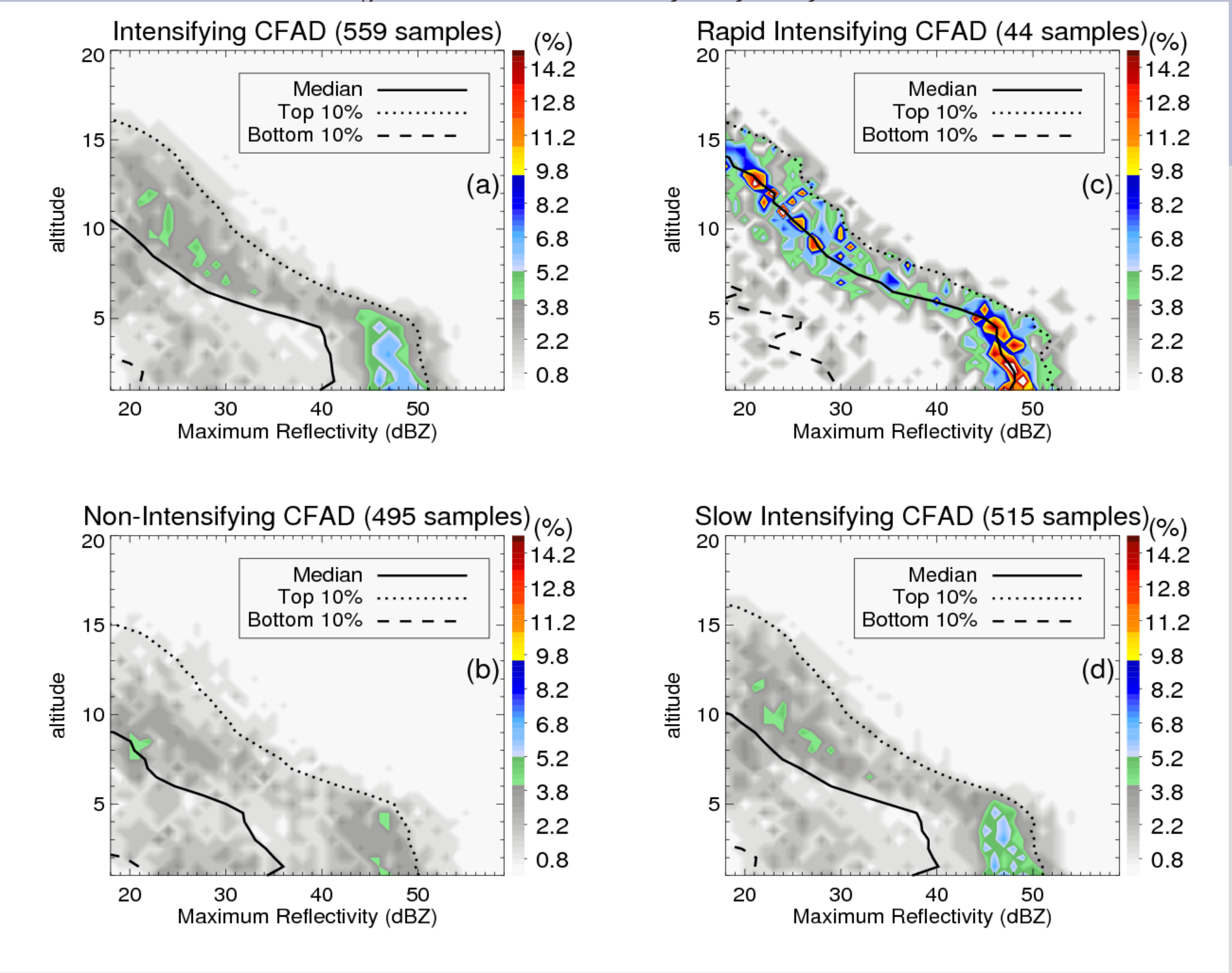
Data and Methodology (Cont.)

- NCEP reanalysis (6 hourly, 2.5x2.5 degree lon/lat resolution) is used for obtaining environmental parameters for each PF.
- TC maximum wind intensity is obtained every six hour from NHC and JTWC. To calculate the 24-h intensity change, we interpolate to find the intensity 12 hours before and after an overflight of TRMM.

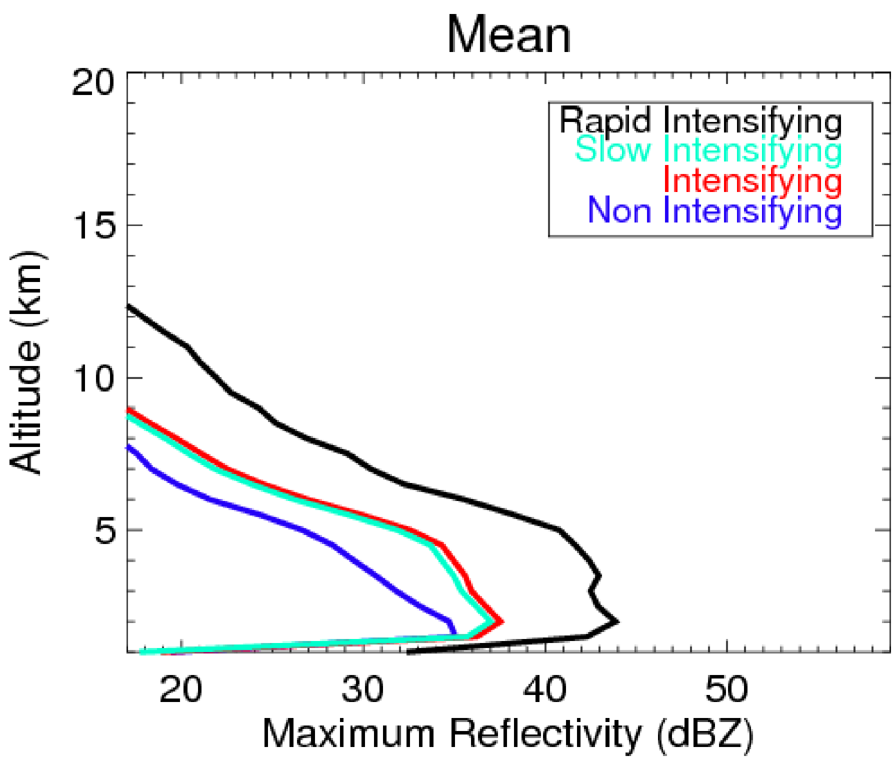
- RI is defined as approximately the 95th percentile of 24-h intensity changes of global TCs during 1998-2006. This is equal to a maximum sustained surface wind speed increase of 30-kt (Kaplan and DeMaria 2003).

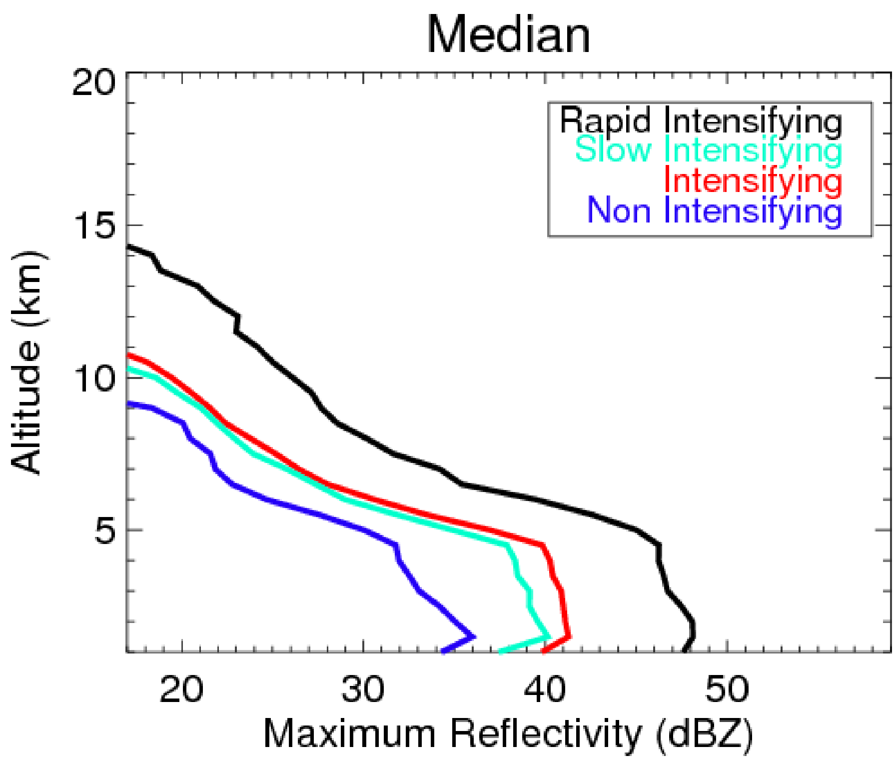


CFAD (Contoured Frequency by Altitude Diagram) of Maximum Reflectivity Profiles for RI, SI, IN, Non-In EW PFs

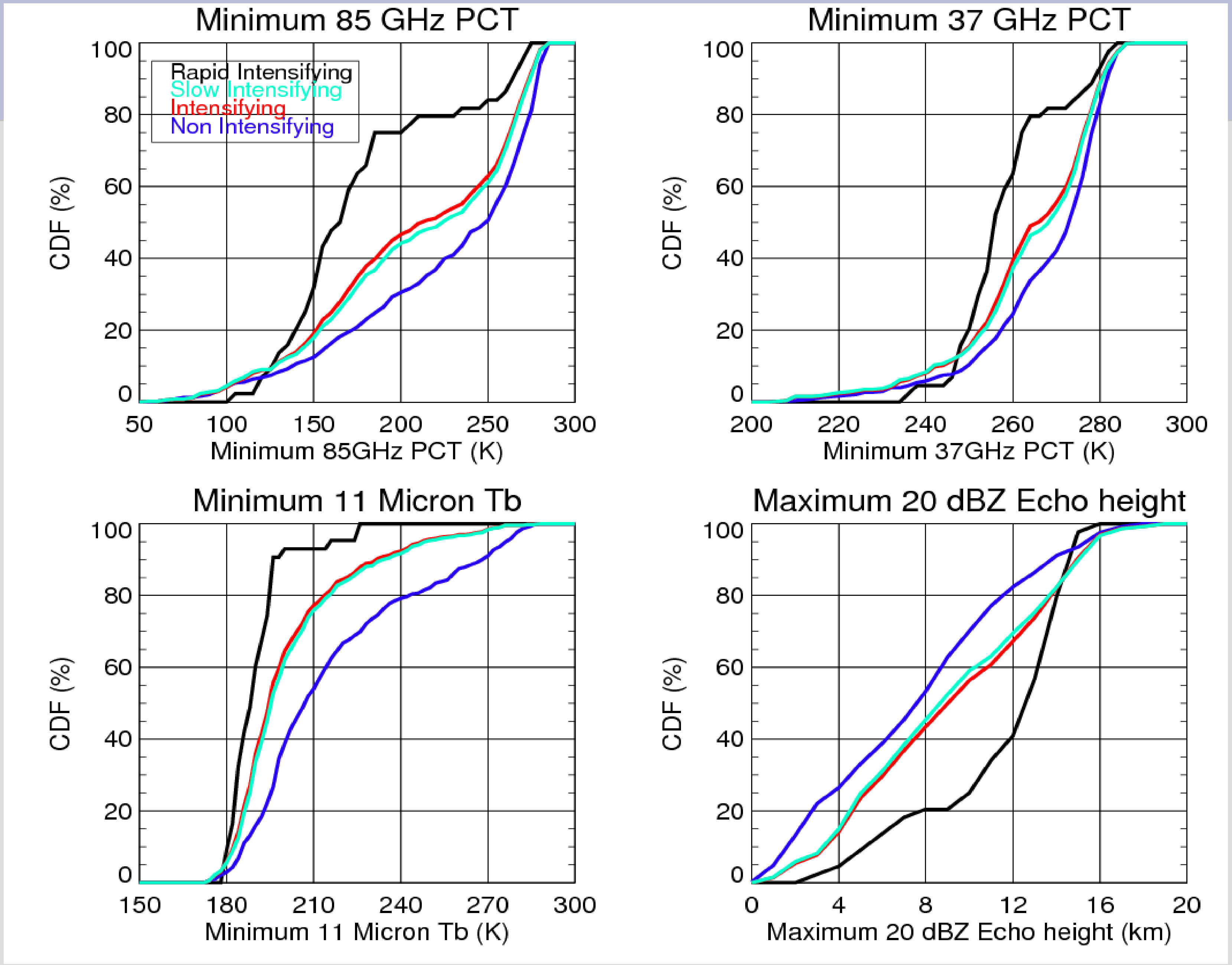


Mean & Median Profiles of Maximum Reflectivity for RI, SI, IN, Non-In EW PFs





CDFs of Min. 85GHz PCT, Min. 37GHz PCT, Min. Tb11, and Max. 20 dBZ Echo Height



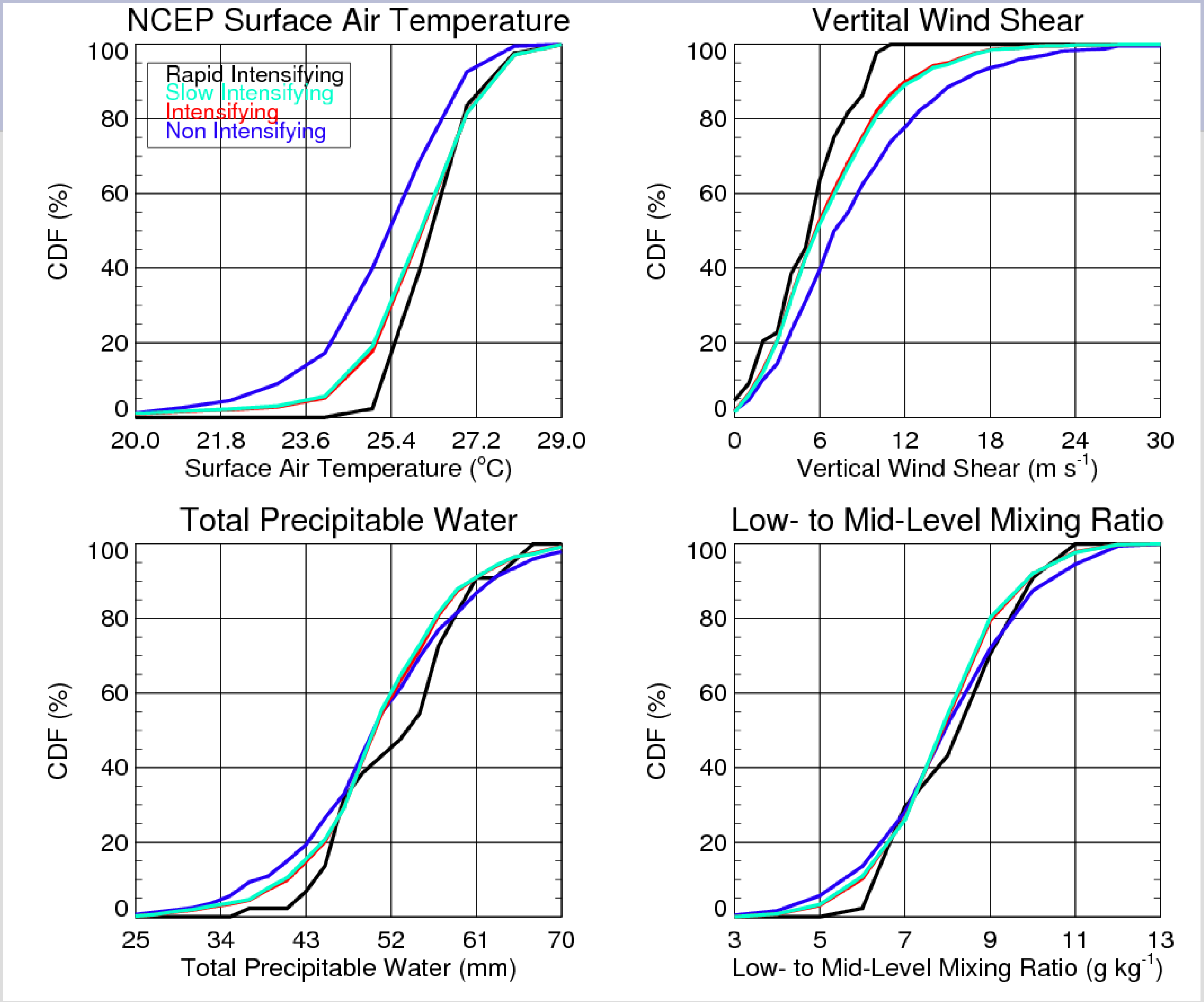
Chance of RI When Hot Tower (HT) Exists

Define HT: Maximum 20 dBZ echo height > 14.5 km (same as Kelly et al. 2004)

	N=EWPFs with HT	N=Total EWPFs	Percentage of EWPFS with HT
RI	12	44	27.27%
SI	105	515	20.39%
IN	117	559	20.93%
NonIN	57	495	11.52%
Chance of RI	6.90%	4.17%	
Chance of SI	60.34%	48.86%	
Chance of IN	67.24%	53.04%	

The chance of RI/IN increases when HT exists, but not substantially. HT is neither a necessary nor a sufficient condition for RI.

CDFs of NCEP Surface Air Temperature, Wind Shear, TPW, and Low- to Mid-level Mixing Ratio



Summary

1. A relationship does exist between TC intensity change and the strength of its convective precipitation features.

2. The mean/median profiles of maximum reflectivity are stronger for EWPFs that undergo RI than SI, and IN than NonIN.

3. Cumulative distribution functions (CDFs) show that the rapidly intensifying (intensifying) TC will have a lower minimum 85/37 GHz PCT and IR Tb11 and higher maximum 20 dBZ height than those of the slow intensifying (non-intensifying) TC.

4. The chance of RI/IN increases when a hot tower exists, but not substantially. A hot tower is neither a necessary nor a sufficient condition for RI.

5. The occurrence of IR/IN is governed not only by the convective processes, but also environmental factors. Our results indicate that the median value of NCEP surface air temperature (vertical shear magnitude) for RI cases is higher (lower) than that for non-RI cases. Similar trend is seen for moisture parameters, but less obvious.