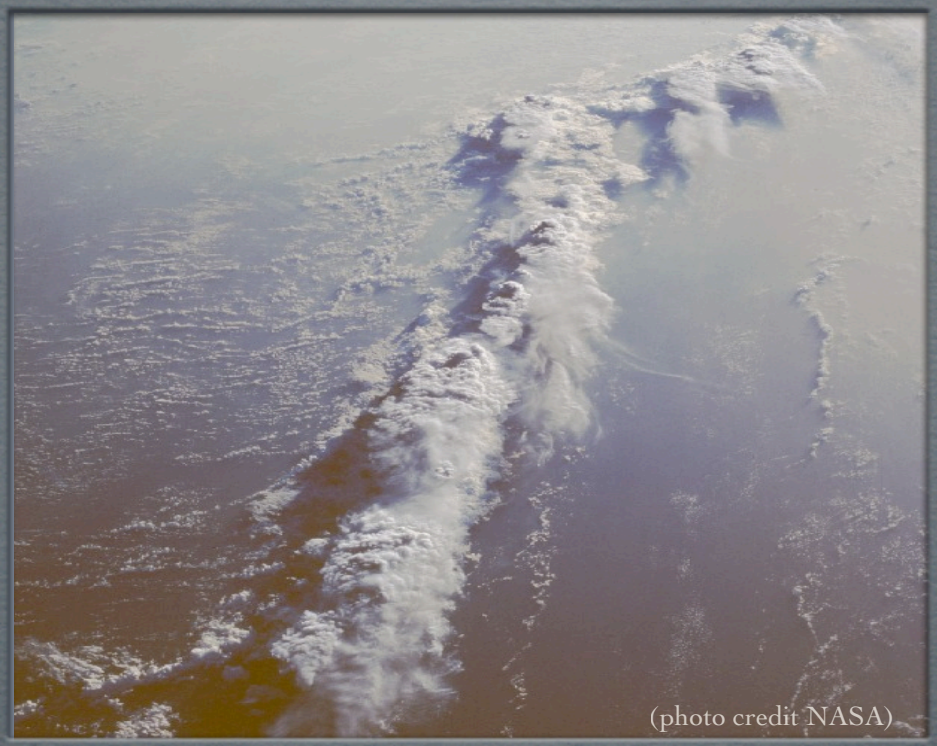

Storm Morphology and Rainfall Characteristics of TRMM Precipitation Features

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TRMM as a Cloud Model Validator

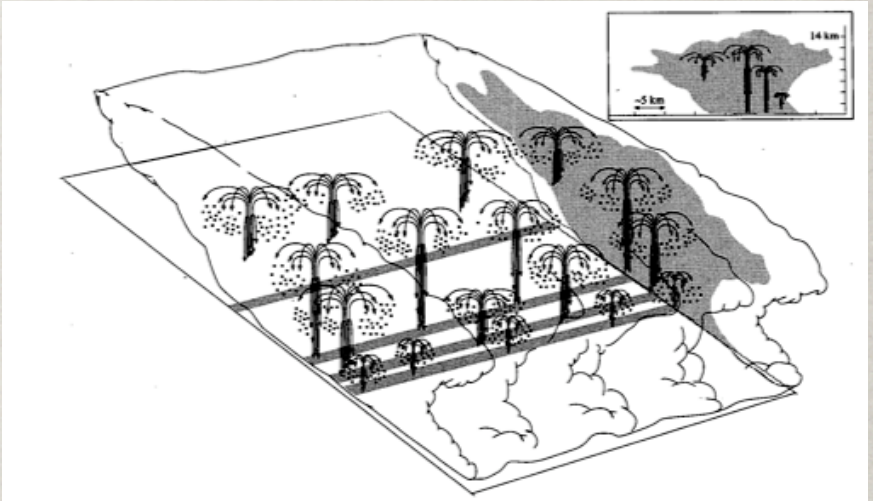
- In the past...
  - "Scale separation" in traditional GCM convective parameterizations make it difficult to compare model and observations (Grabowski 2004)
- But now...
  - Global CRM's and MMFs exist which resolve convective systems, and can gererate statistics of "observable" quantities for evaluation of cloud structures in both the horizontal and vertical
  - TRMM can provide statistical validation of CRM simulations of the horizontal and vertical structure of precipitation, especially for deep convective systems

Motivation

- Many previous studies have examined the horizontal structure of storms:
  - IR cloud clusters regionally (e.g., Williams and Houze 1987, Mapes and Houze 1993) and globally (e.g., Machado and Rossow 1998)
  - Radar echoes regionally using ground based radar (López 1977, Rickenbach and Rutledge 1998) and the TRMM PR (Nesbitt et al. 2000)
  - With TRMM, we can examine the spatial variation of ***rainfall*** Tropics-wide and obtain "climatological" averages of storm characteristics

Factors influencing rainfall systems' horizontal structure

- Convective Forcing
- Convective and Mesoscale Dynamics
- Microphysics, Rainfall
- Convective system-Large Scale Feedbacks

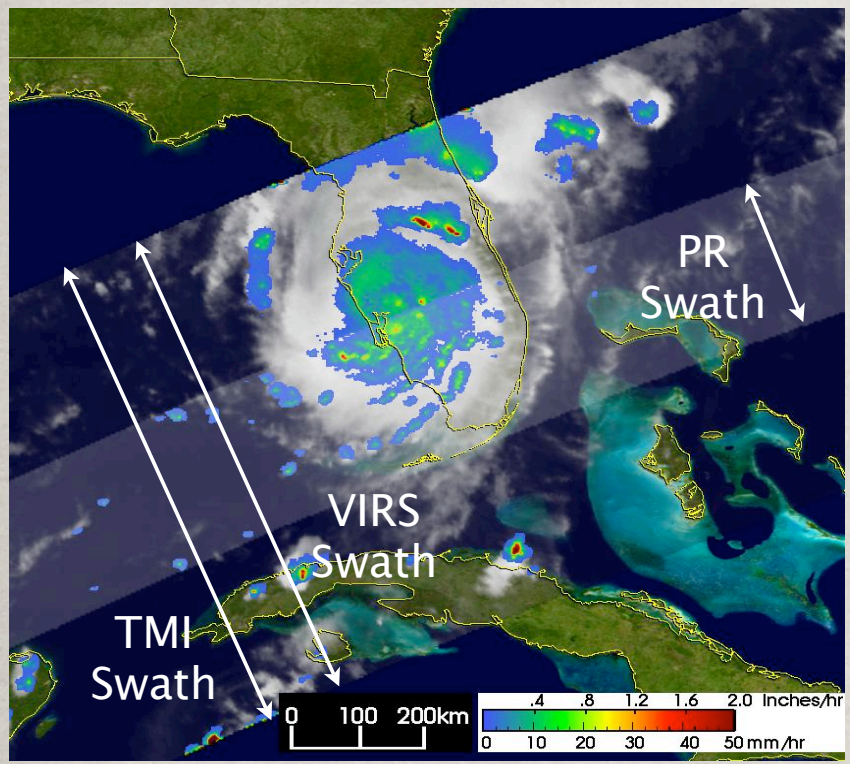


Yuter and Houze (1995)

Goals of this study

- What is the parameter space of the precipitating features' echo horizontal dimension?
- How do features of various horizontal scales contribute to rainfall in a given region?
- What is the relationship between vertical and horizontal structure of these systems?
- How do storms of different types scale in rainfall contribution as a function of total rainfall?

TRMM Instruments



http://trmm.gsfc.nasa.gov

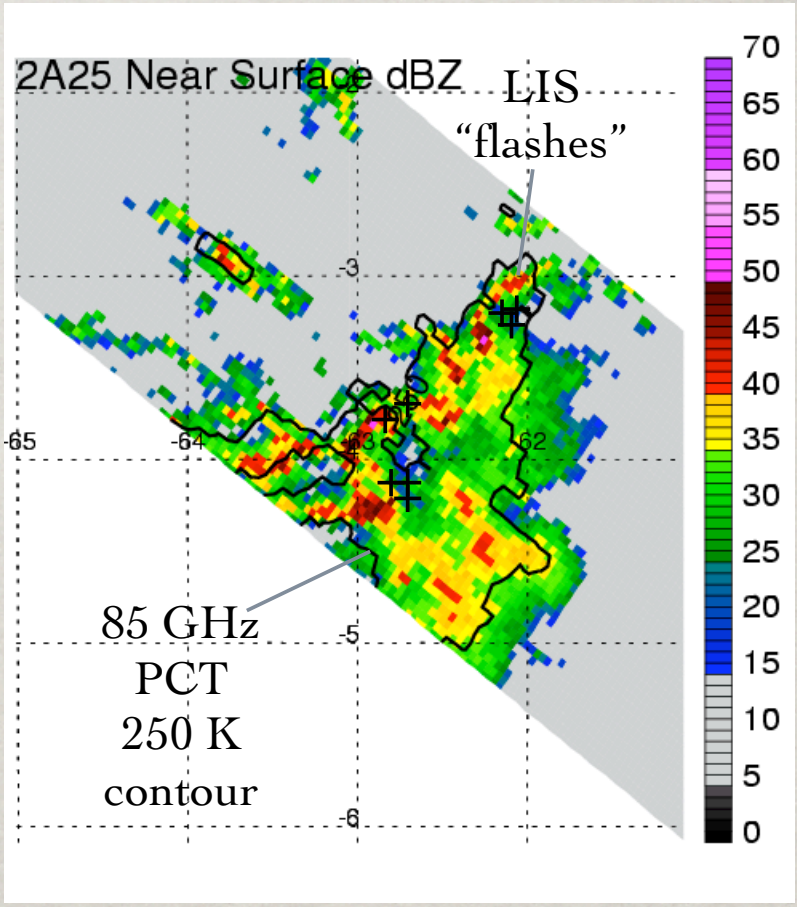
- Precipitation Radar (PR)
  - 215 km swath
  - K_a Band - 14 GHz - 2.2 cm
  - 17 dBZ minimum detectable signal
  - 4 x 4 x 0.25-1.5 km resolution
  - Calibrated to within ± 1 dBZ
- TRMM Microwave Imager (TMI)
  - 759 km swath
  - 9 channels, 10 - 85 GHz, dual polarization, elliptically-scanning
  - Resolution varies from 5 x 7 km at 85 GHz to 60 x 60 km at 10 GHz
  - Rainfall retrievals based on different physics over land and ocean
- Visible and Infrared Scanner (VIRS)
  - 720 km swath
  - Measures radiances at 5 channels from 0.6-12 μm

The Precipitation Feature Database

- Joint effort among University of Utah, Colorado State University, University of Alabama at Huntsville, NASA GSFC/TSDIS
- Brought forth a massive meteorological "data mining" effort to identify and classify rain systems within the TRMM PR and TMI swaths
- With "version 6" reprocessing, we have transitioned processing to GSFC
  - Level 1: PR/TMI/VIRS/LIS data compressed by a factor of 40
  - Level 2: Statistics calculated for PR-only, PR/TMI, and TMI-only identified precipitation features
- Roughly 36 million PR-defined PFs identified between 1998 -2004

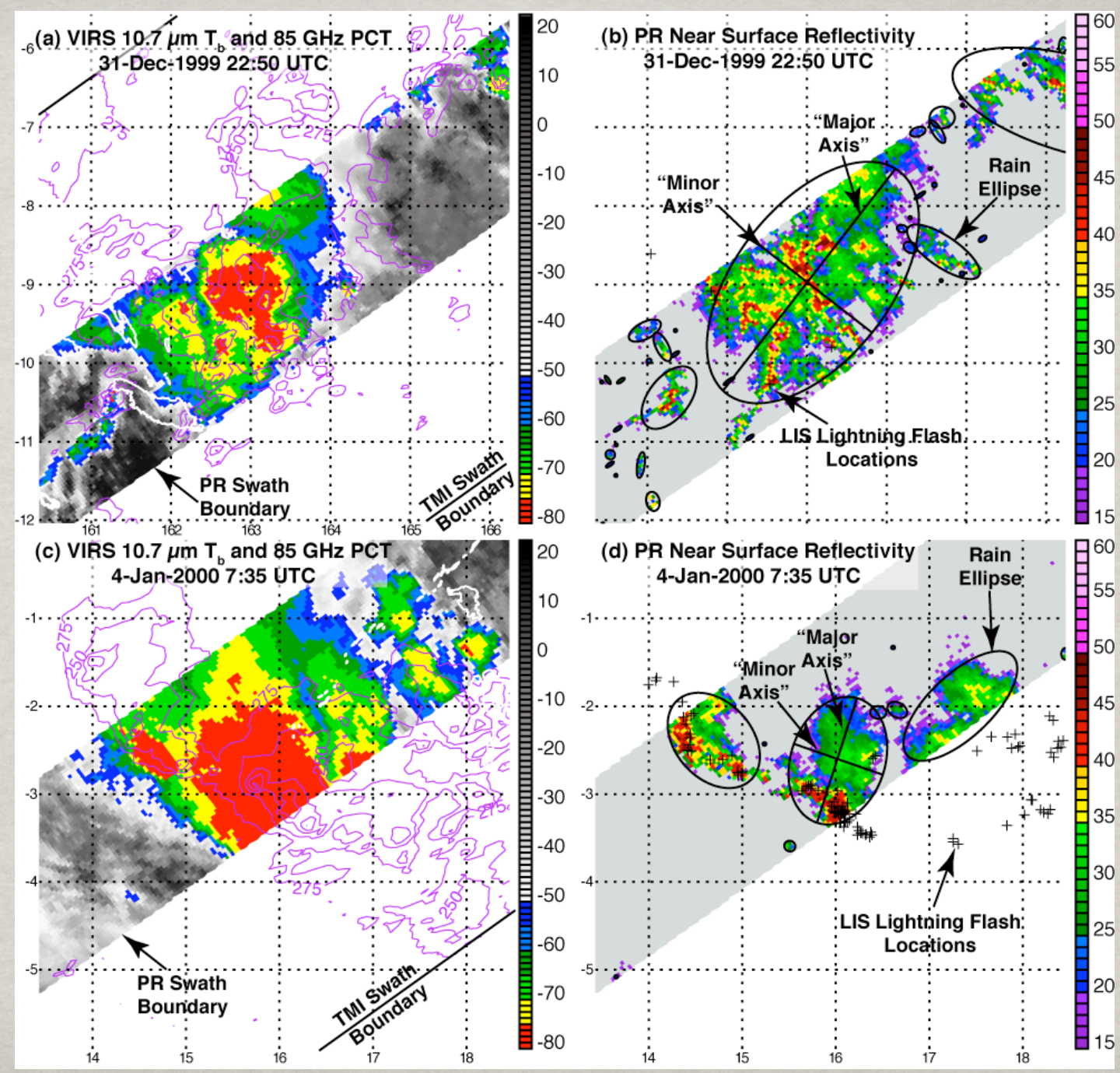
Methodology

- A PF is defined as an area of contiguous pixels with PR reflectivity ≥ 20 dBZ
- For this study, we analyzed 3 years of version 6 PFs(1998-2000)
- Ellipses are fitted to the perimeter of each PF using a least squares technique to estimate maximum dimension

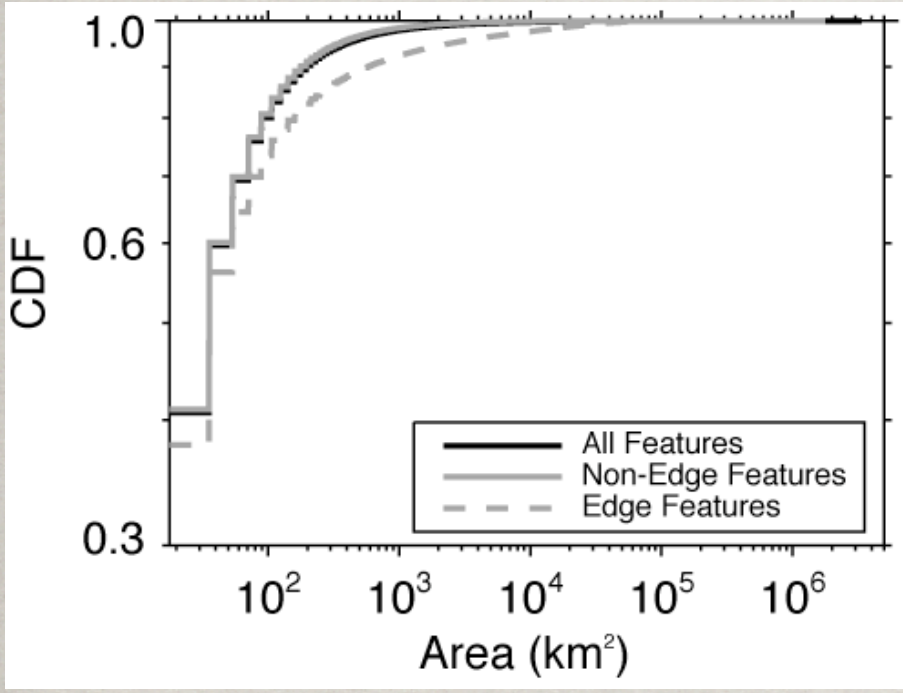


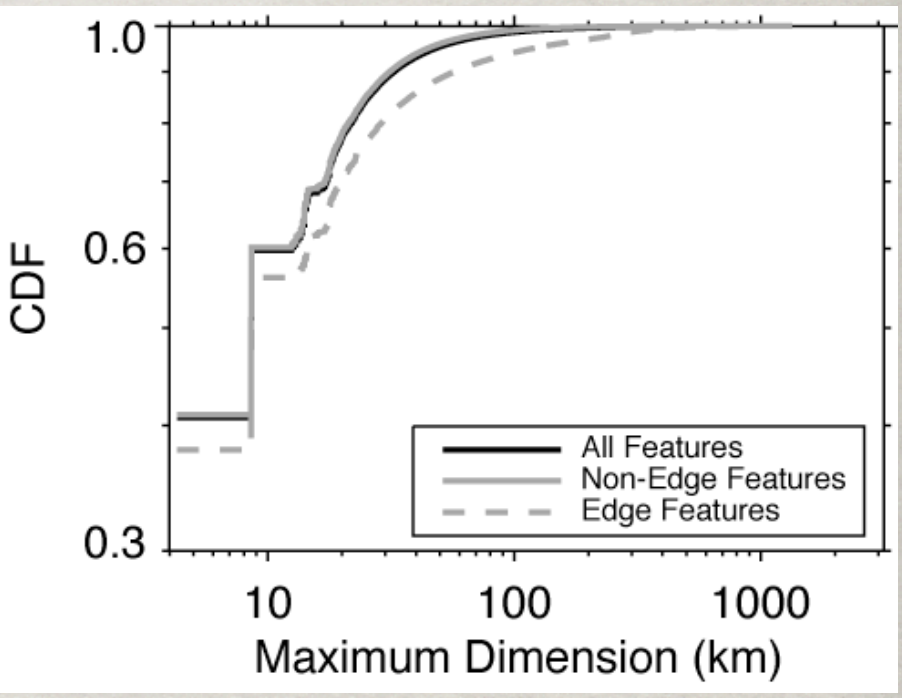
Tropical West Pacific

Congo Basin

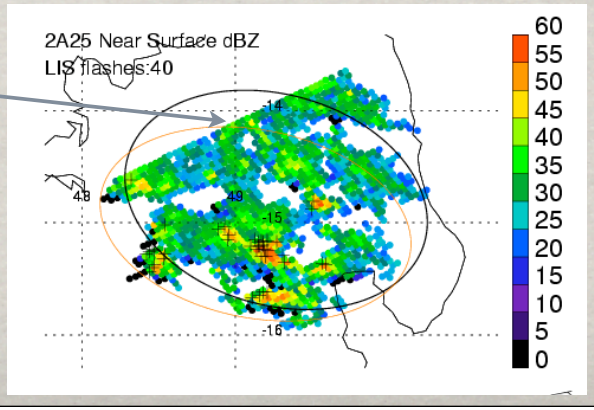


CDF of feature area for those hitting and not hitting the edge of the PR swath

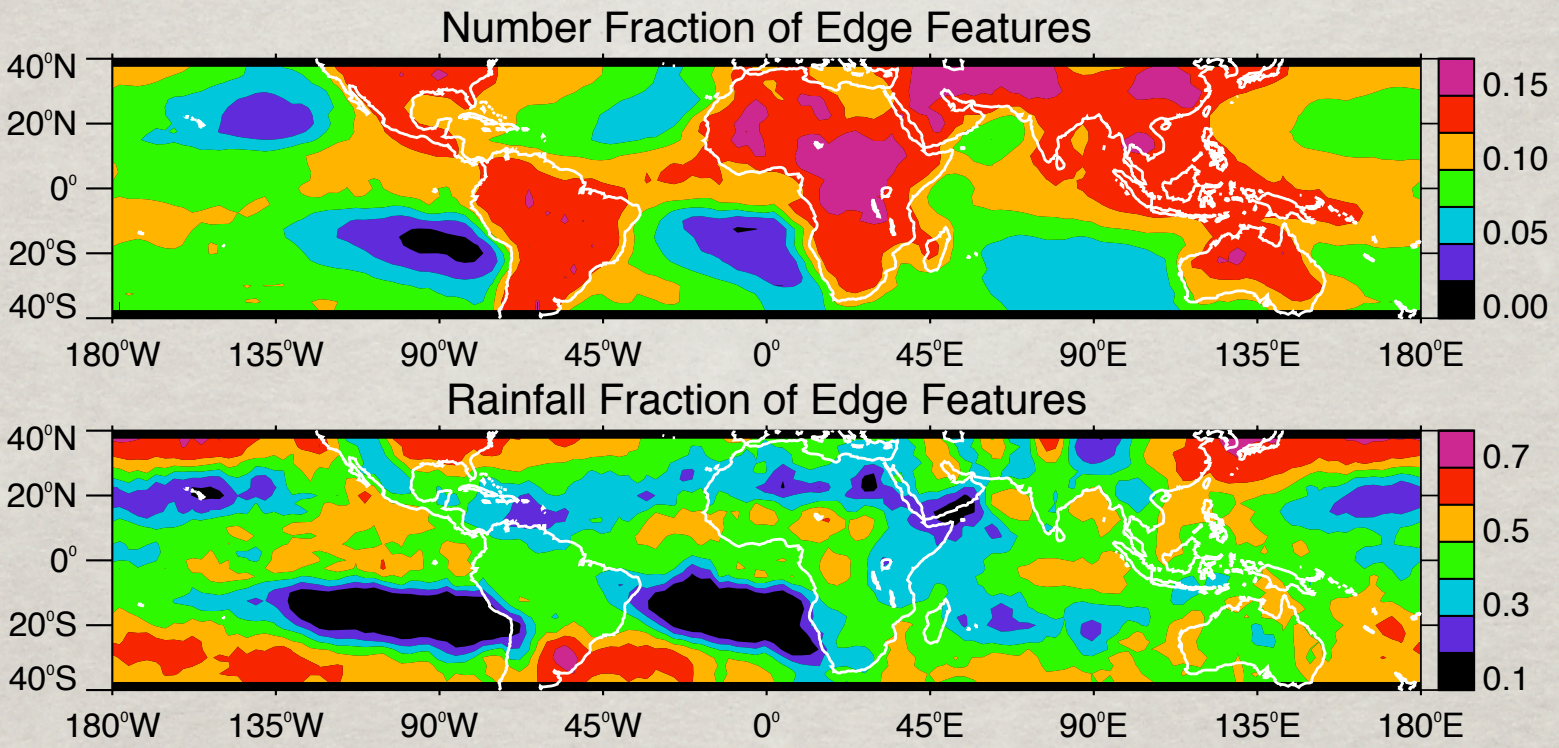




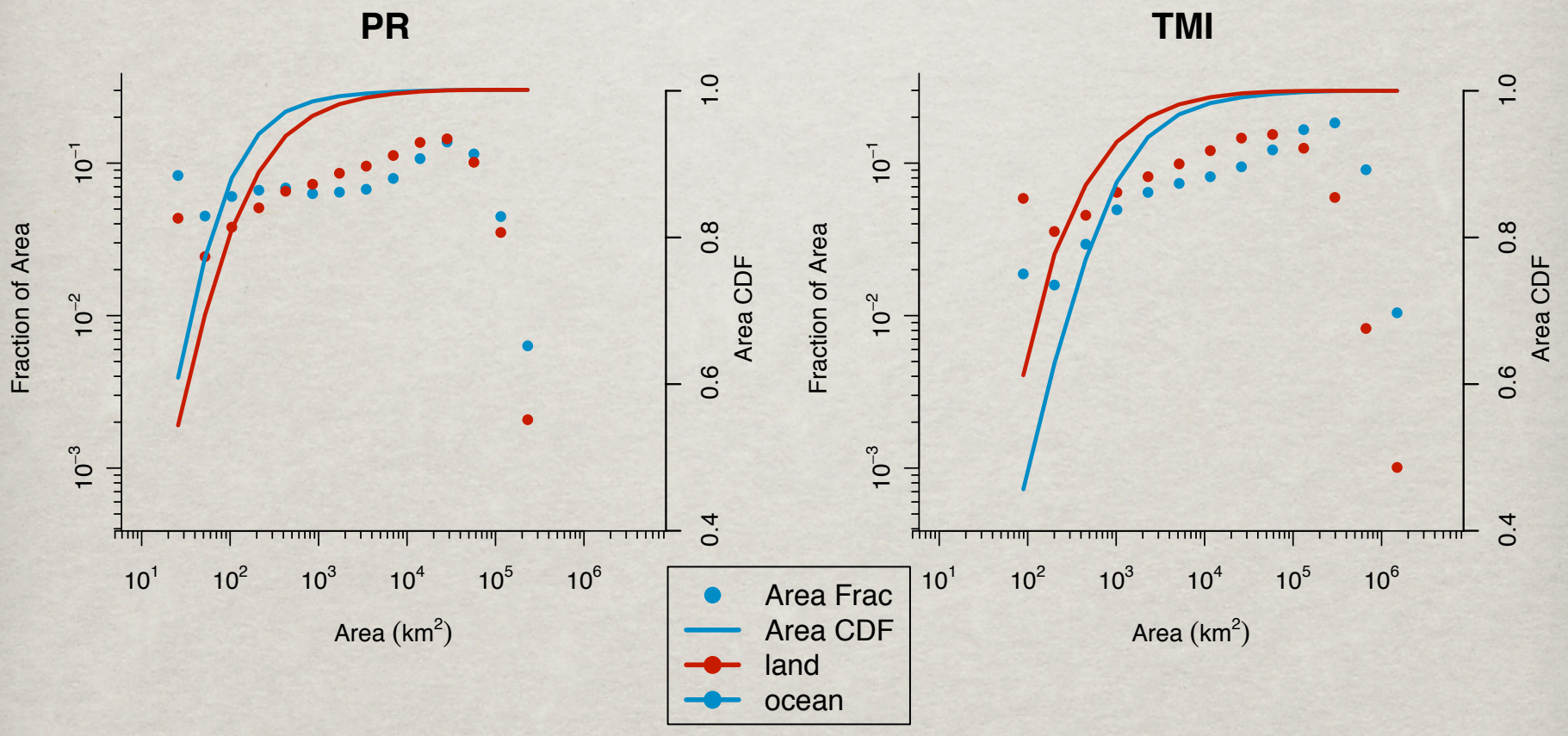
Edge of PR swath



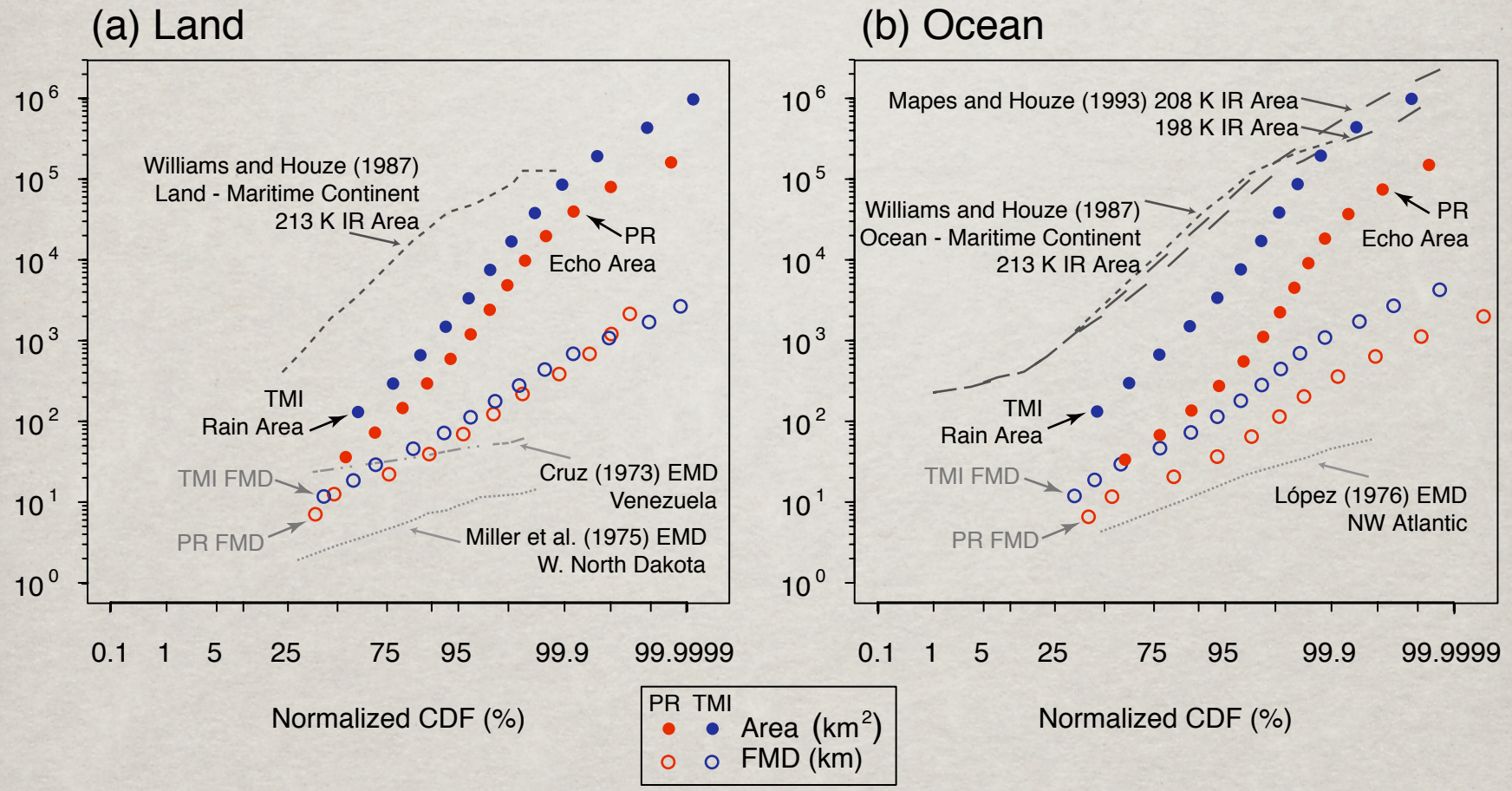
Population and rainfall of PR edge features



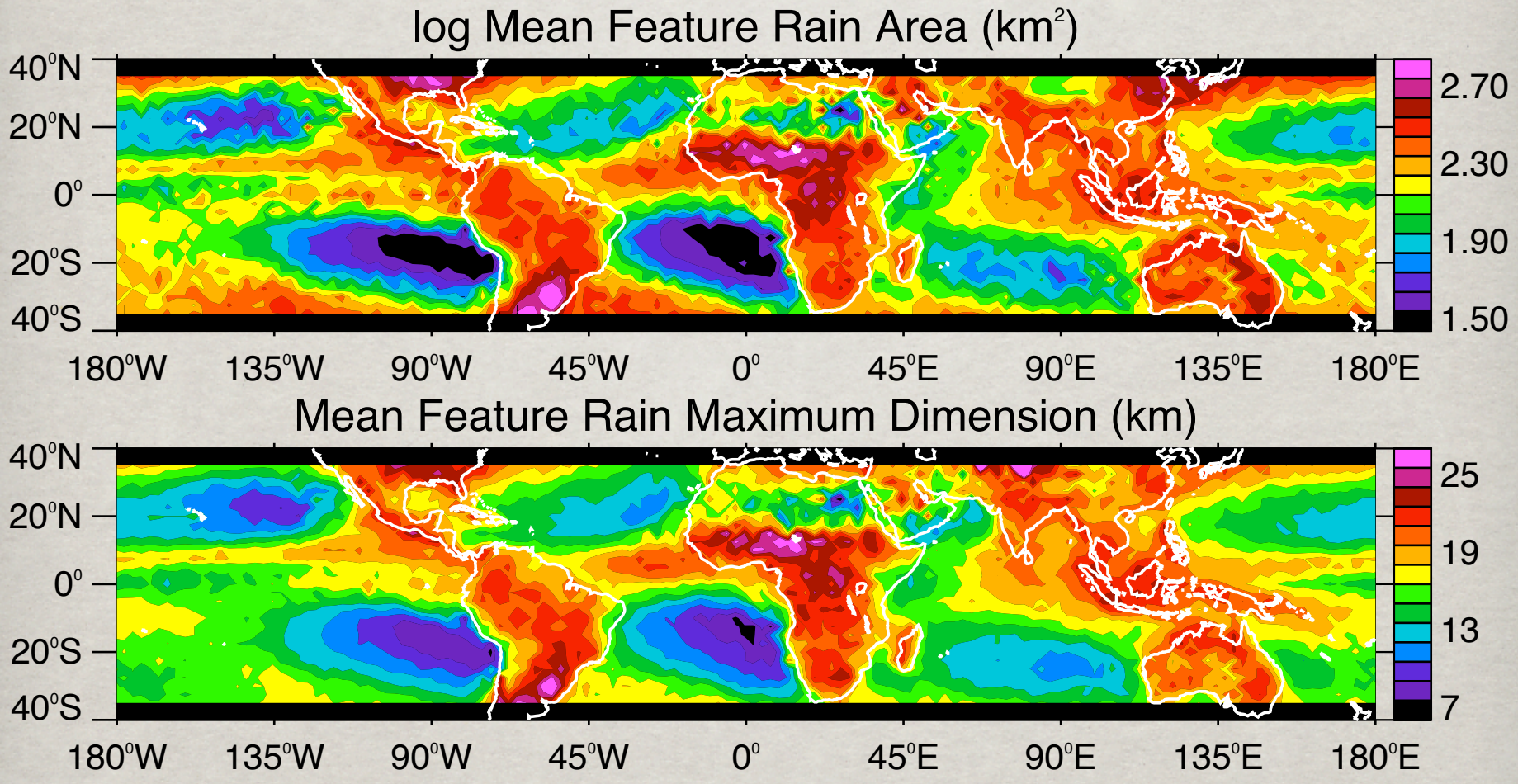
Distributions of feature area over land and ocean comparing PR 2A25 and TMI 2A12 near surface rain



Feature size distributions on log-normal paper



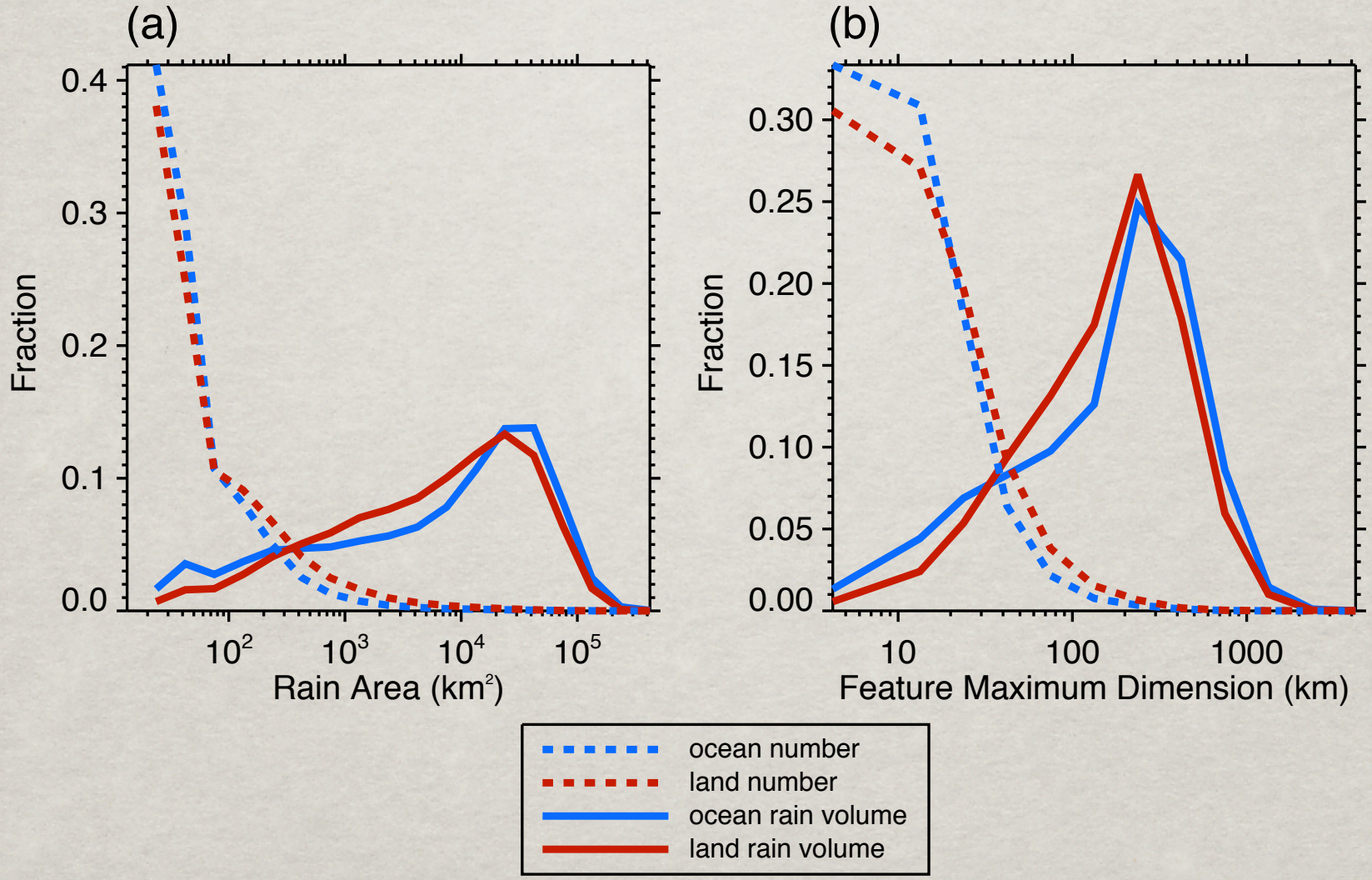
Regional feature size variability

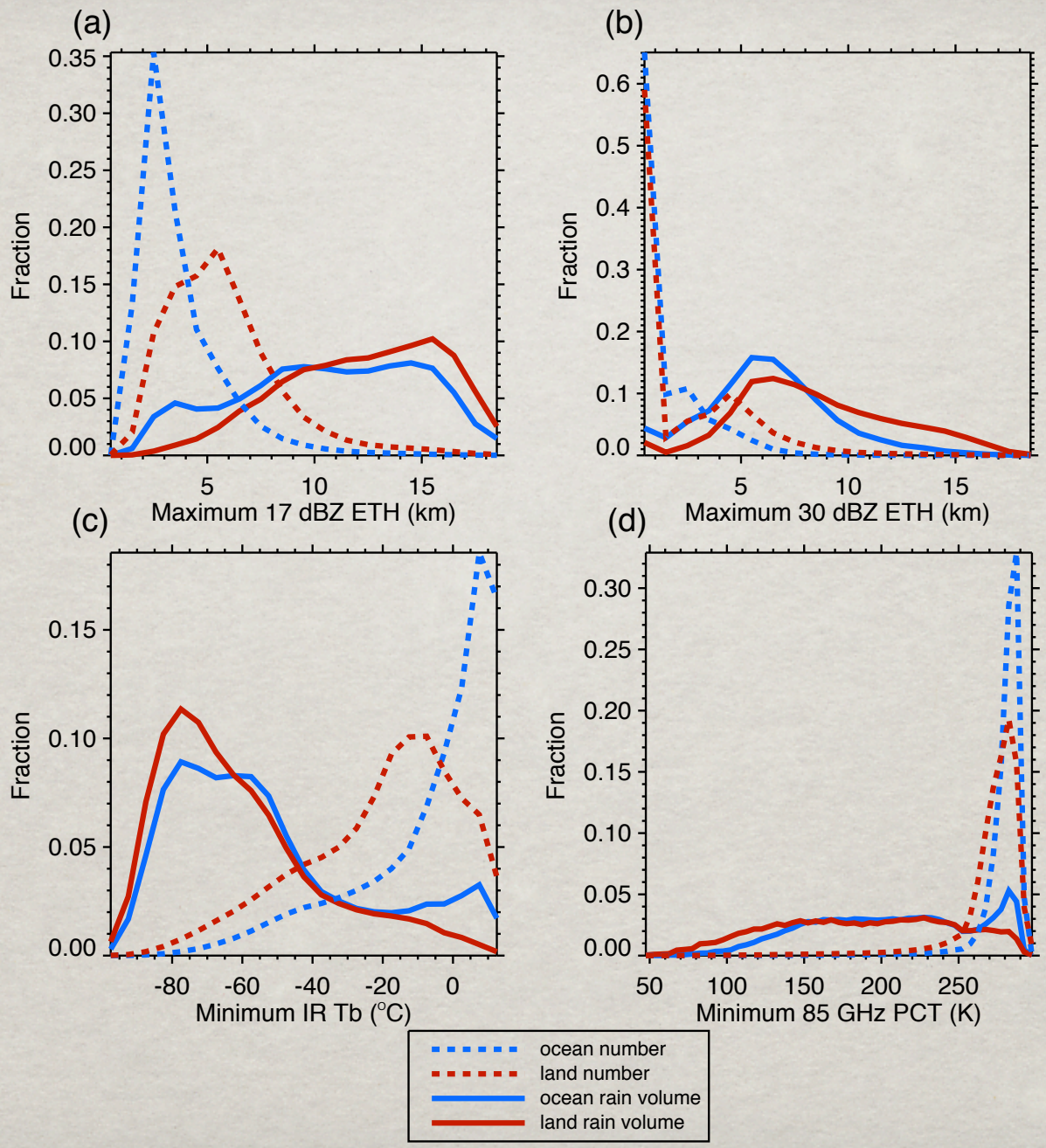


Selected feature characteristics

	Ocean	Land
Number of features ($\times 10^3$)	15389	2733
Number fraction	.82	.18
Mean RR_{cond} (mm/hr)	2.71	2.81
Mean RR_{uncond} (mm dy^{-1})	2.48	2.02
Mean feature area (km^2)	189	371
Mean feature maximum dimension (km)	17	21
Fraction of rain stratiform	.54	.48

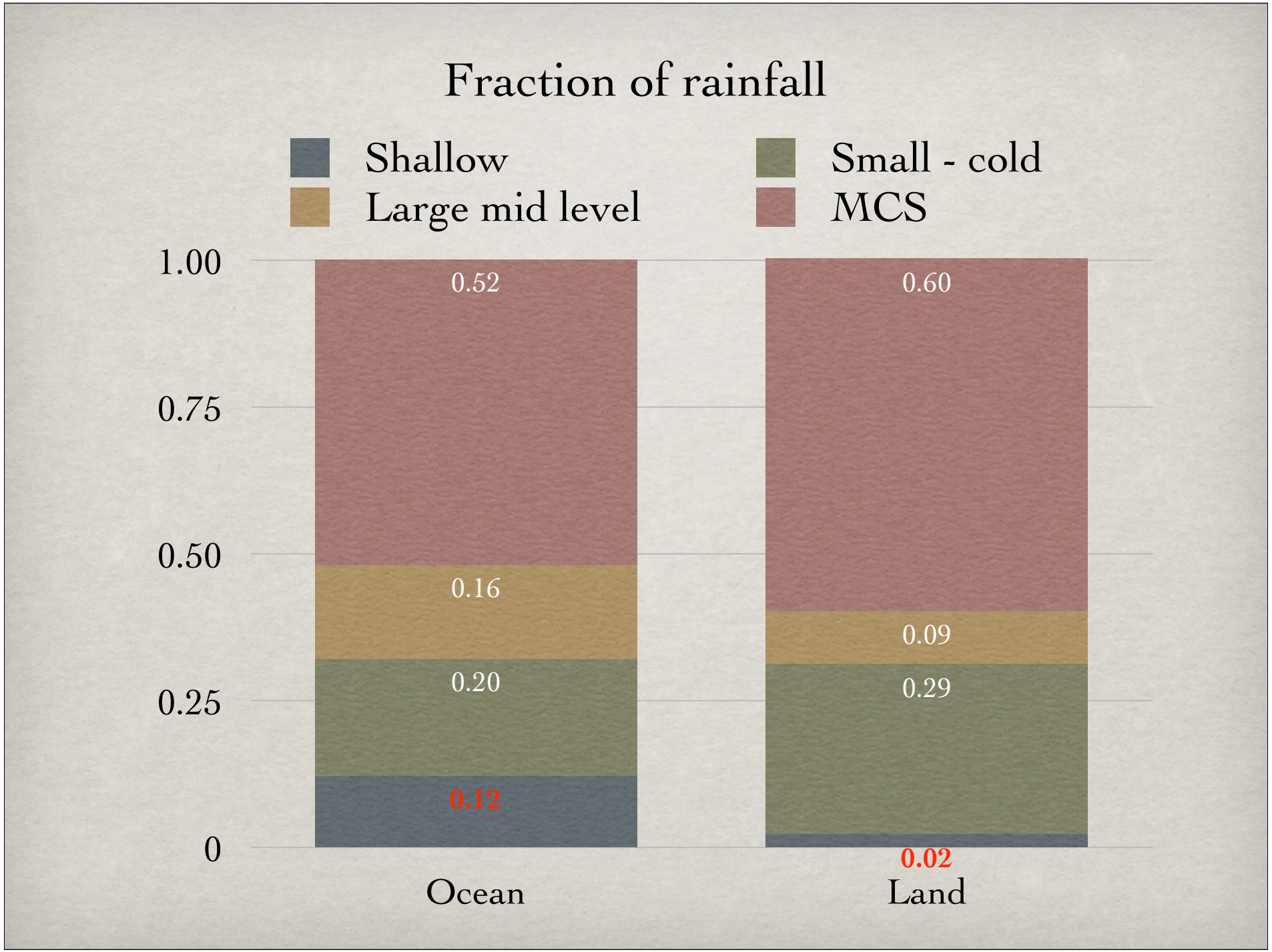
Frequency distributions of feature size and rainfall contribution



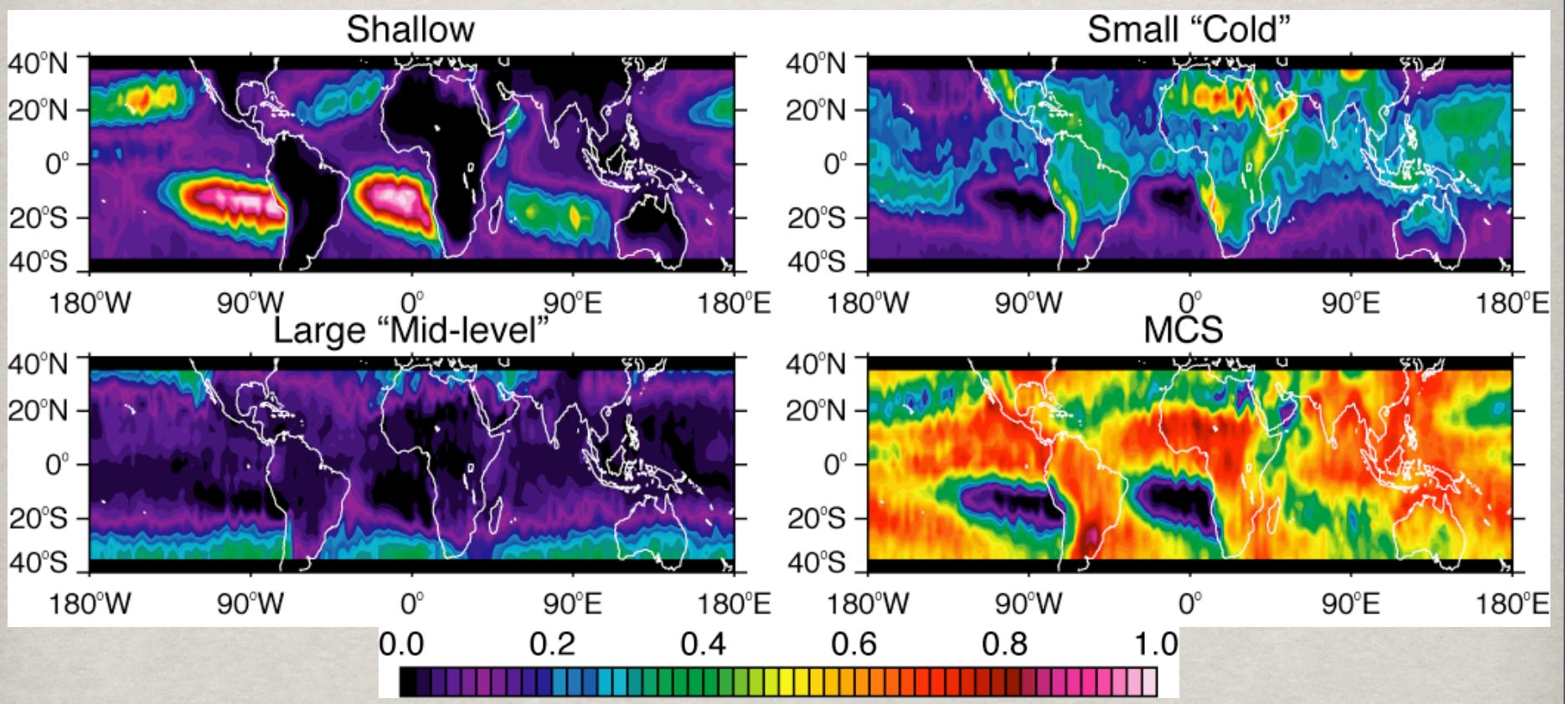

(a)
Fraction
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
5
10
15
Maximum 17 dBZ ETH (km)
(b)
Fraction
0.6
0.5
0.4
0.3
0.2
0.1
0.0
5
10
15
Maximum 30 dBZ ETH (km)
(c)
Fraction
0.15
0.10
0.05
0.00
-80
-60
-40
-20
0
Minimum IR Tb (°C)
(d)
Fraction
0.30
0.25
0.20
0.15
0.10
0.05
0.00
50
100
150
200
250
Minimum 85 GHz PCT (K)
ocean number
land number
ocean rain volume
land rain volume

Feature type definition

	Feature maximum dimension	PR 17 dBZ echo top
PF Type	FMD criteria	ETH criteria
Shallow (S)	-	ETH ≤ 4.5 km (MSL)
Small "Cold" (SC)	FMD < 100 km	ETH > 4.5 km
Large "Mid-level" (LM)	FMD ≥ 100 km	4.5 > ETH > 9.5 km
MCS	FMD ≥ 100 km	ETH ≥ 9.5 km


Fraction of rainfall
Shallow
Small - cold
Large mid level
MCS
1.00
0.75
0.50
0.25
0
0.52
0.16
0.20
0.12
0.60
0.09
0.29
0.02
Ocean
Land

Rainfall fraction by feature type



Examination of rainfall budgets

Total rain volume

number of features

mean feature area

$$\sum R_{\text{vol}} = A_r \overline{RR_{\text{cond}}} = n_f \overline{A} \overline{RR_{\text{cond}}}$$

raining area

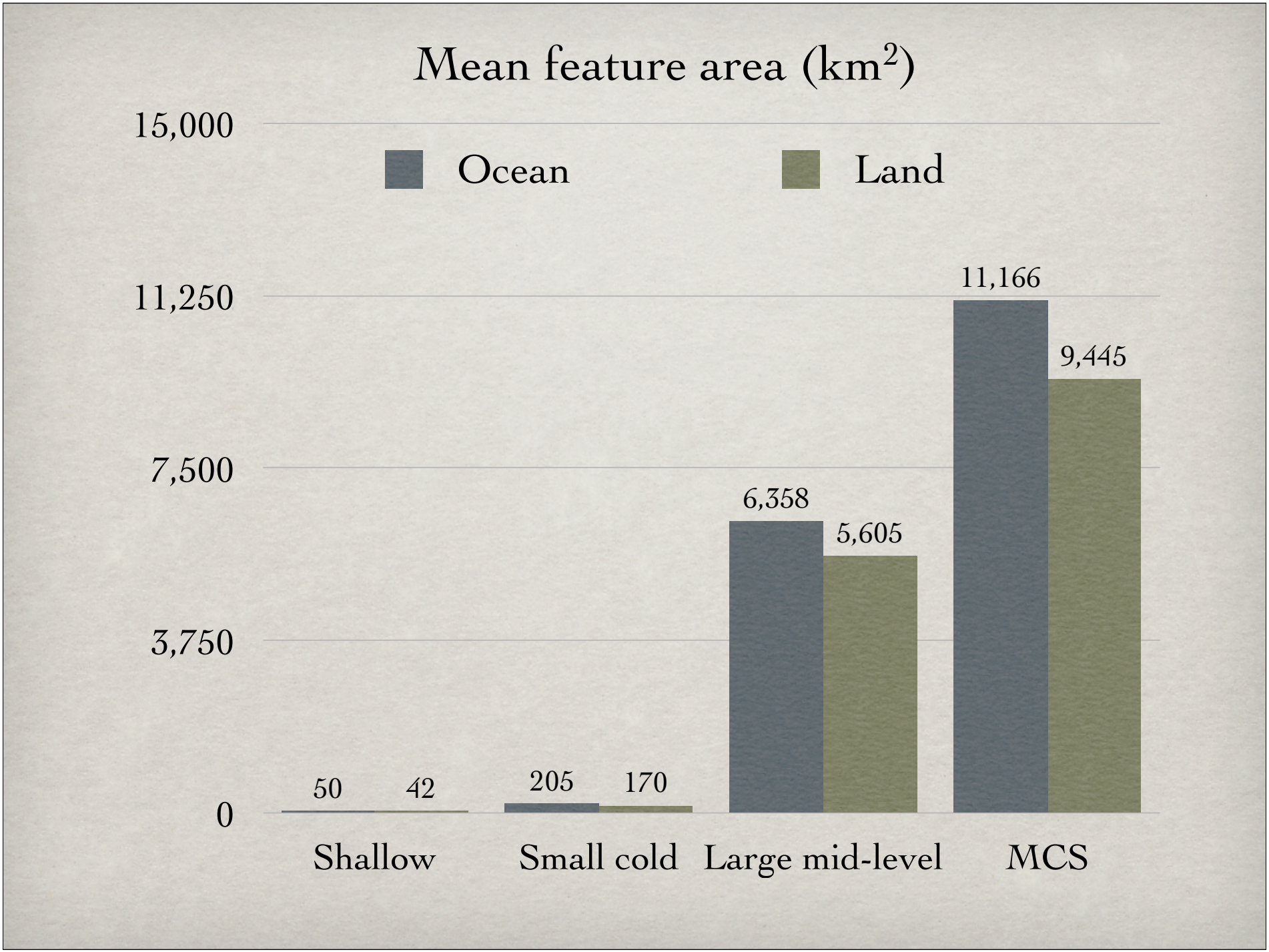
mean conditional rain rate

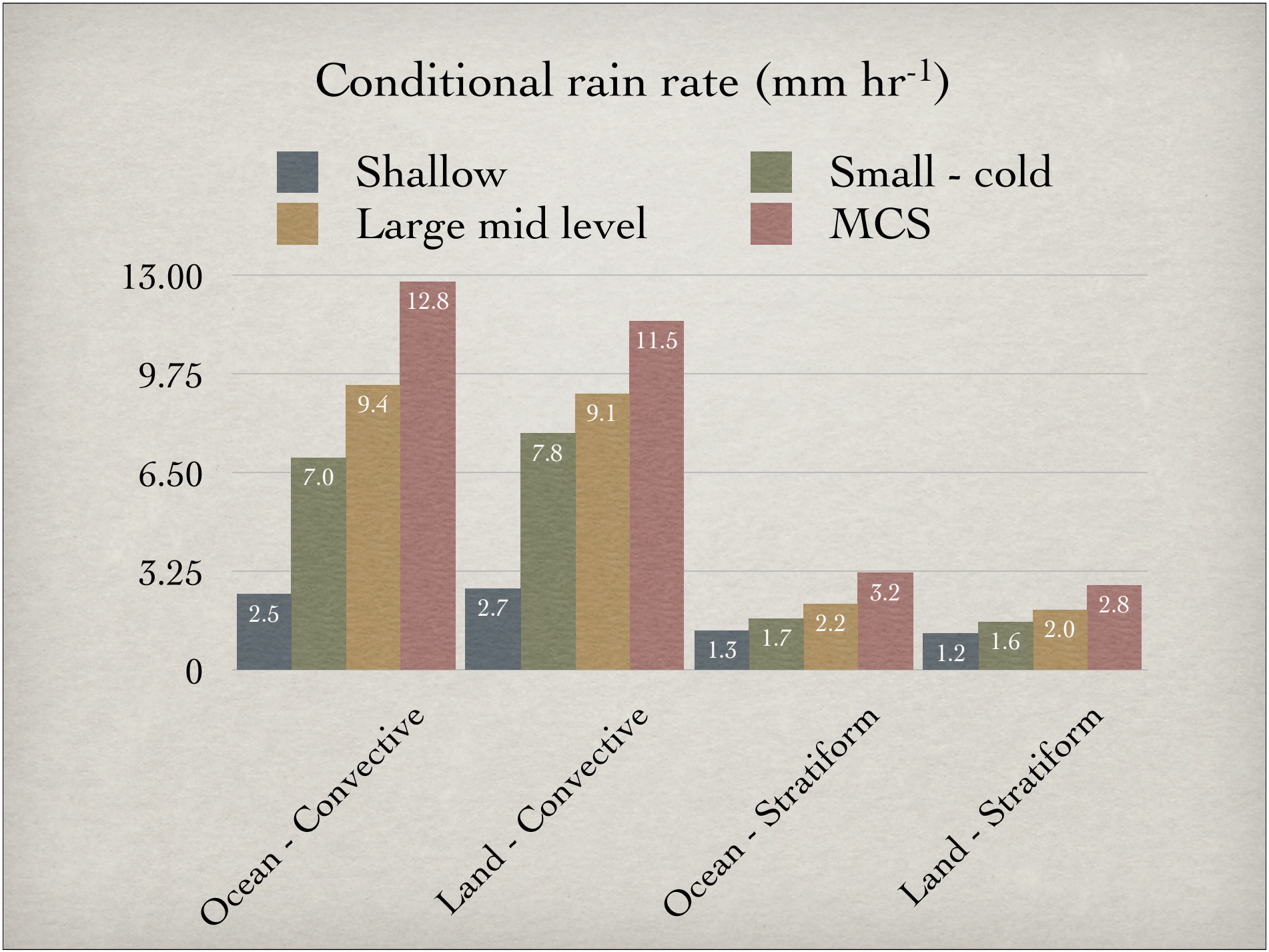
$$= n_f \overline{A} \left[f_{a_s} \overline{RR_{\text{cond}_s}} + \left(1 - f_{a_s}\right) \overline{RR_{\text{cond}_c}} \right]$$

fraction of area stratiform

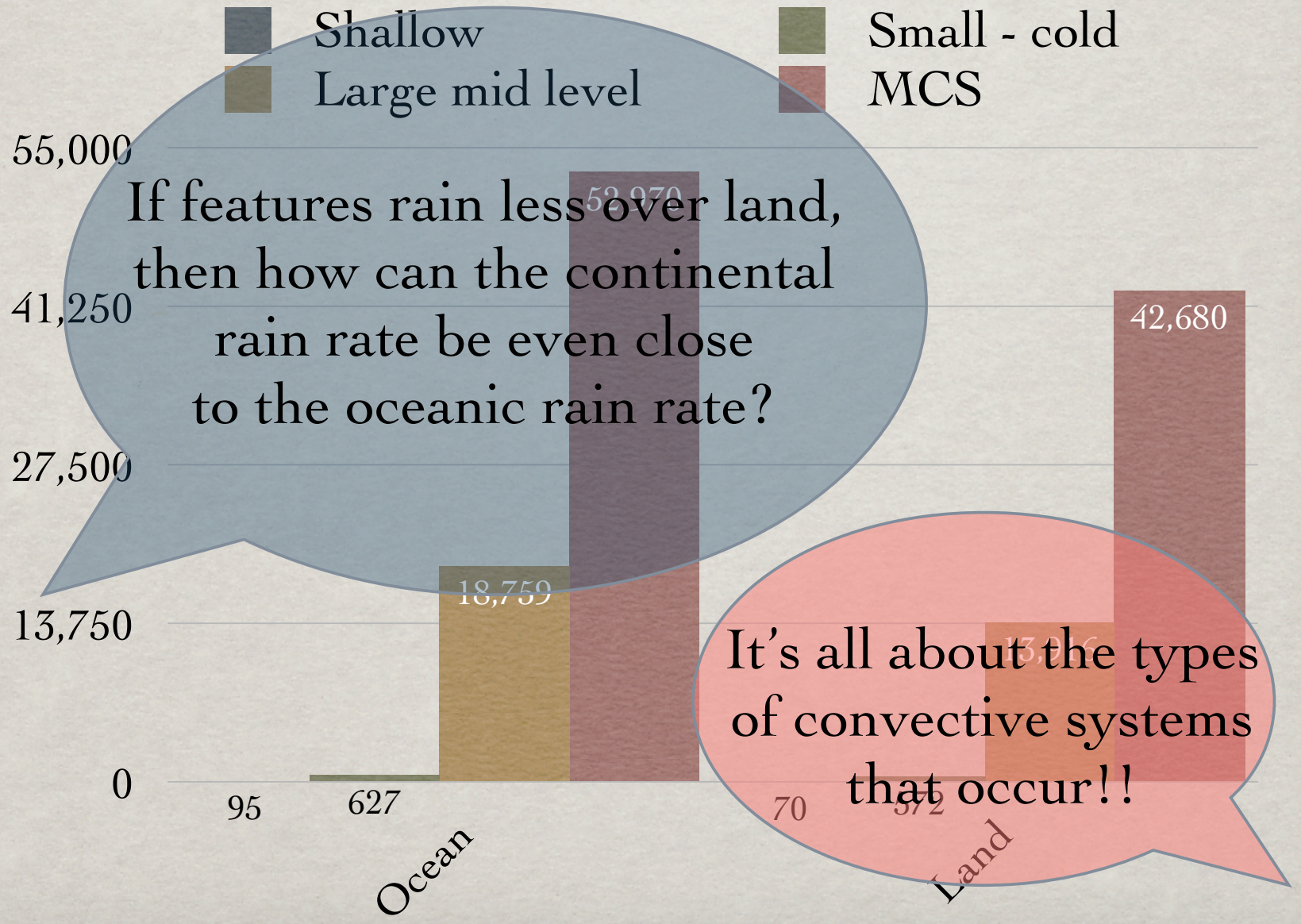
mean stratiform conditional rain rate

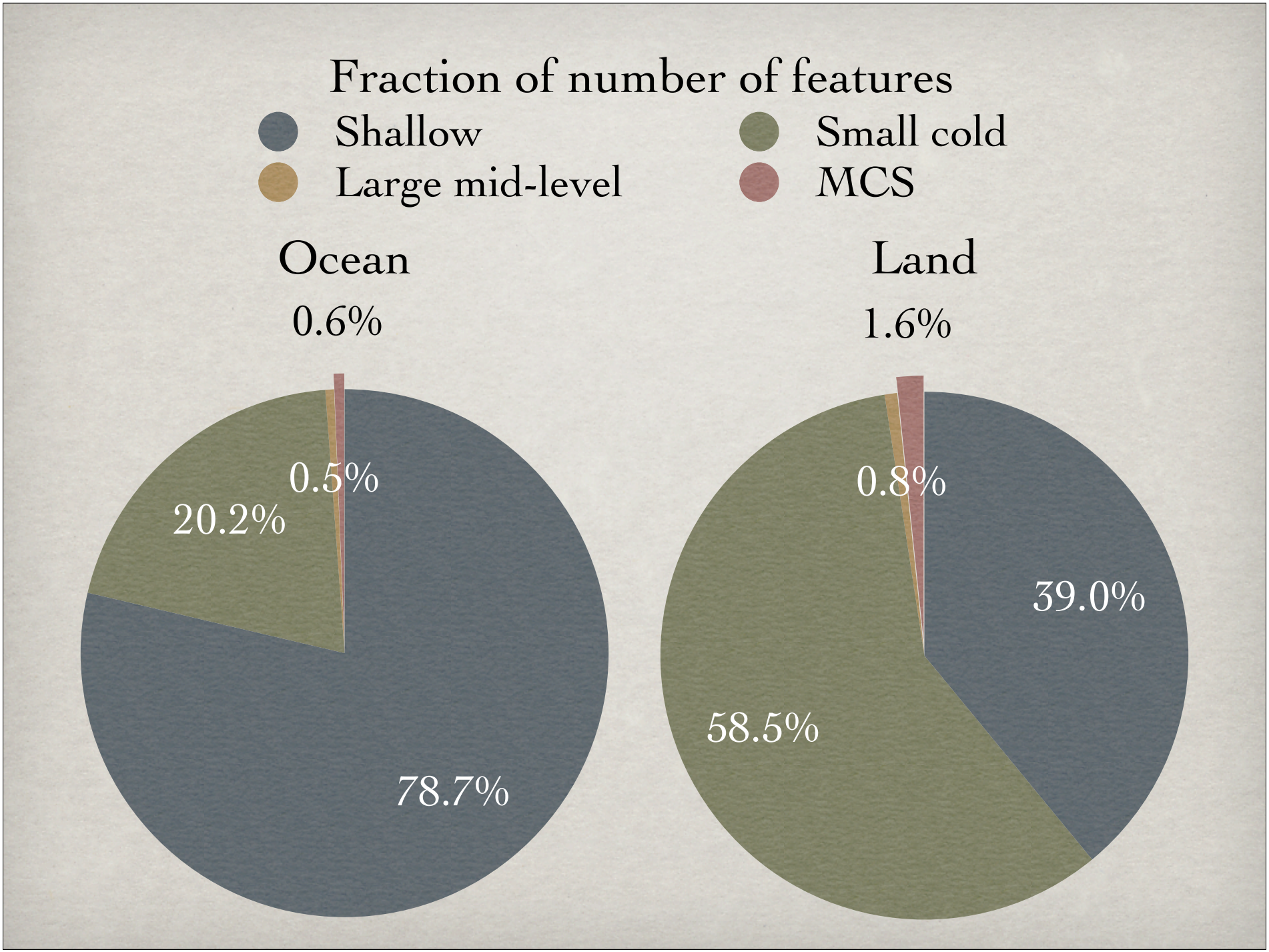
mean convective conditional rain rate


Mean feature area (km²)
15,000
11,250
7,500
3,750
0
Ocean
Land
50
42
205
170
6,358
5,605
11,166
9,445
Shallow
Small cold
Large mid-level
MCS

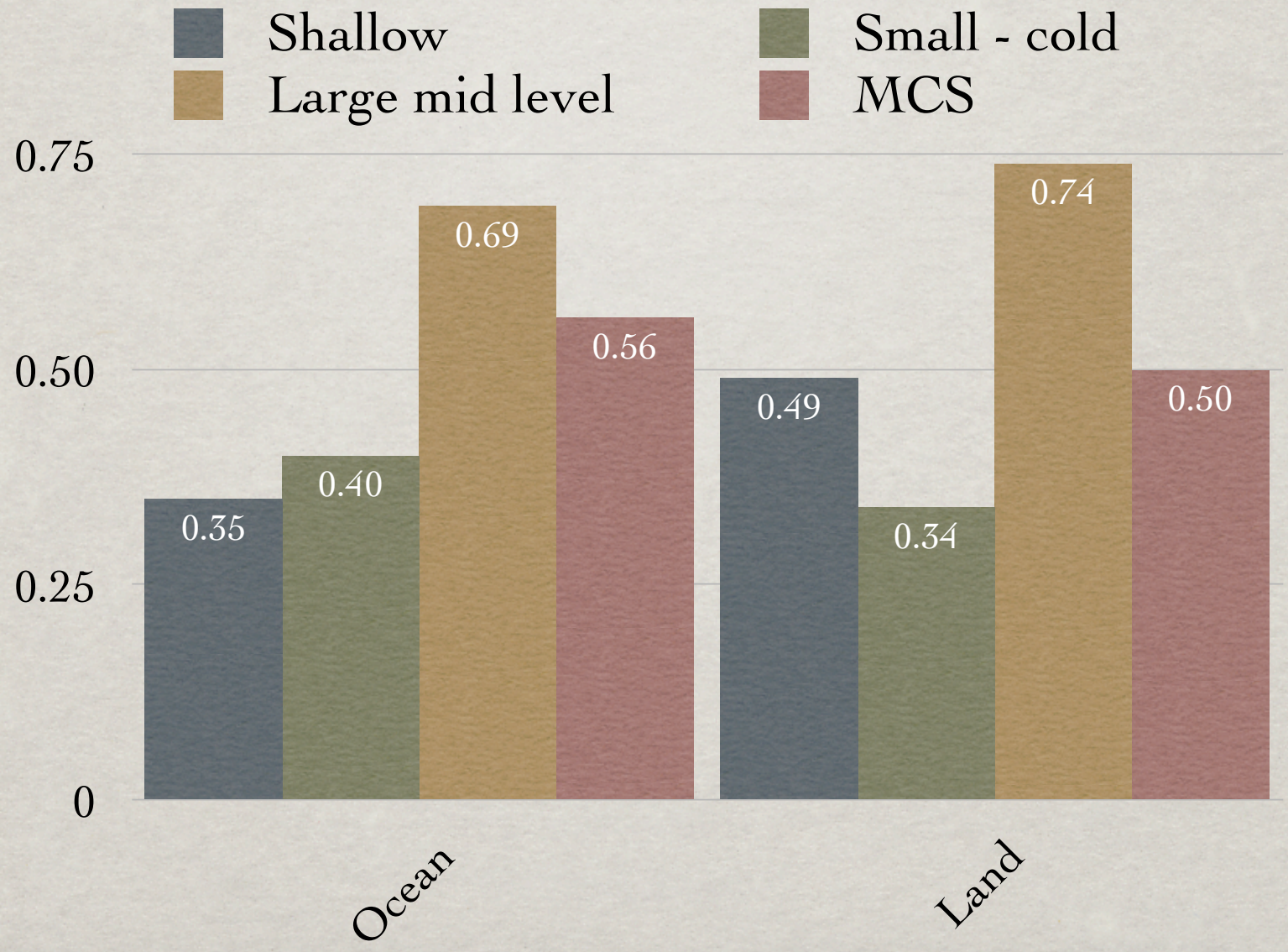

Conditional rain rate (mm hr-1)
Shallow
Small - cold
Large mid level
MCS
13.00
9.75
6.50
3.25
0
2.5
7.0
9.4
12.8
2.7
7.8
9.1
11.5
1.3
1.7
2.2
3.2
1.2
1.6
2.0
2.8
Ocean - Convective
Land - Convective
Ocean - Stratiform
Land - Stratiform

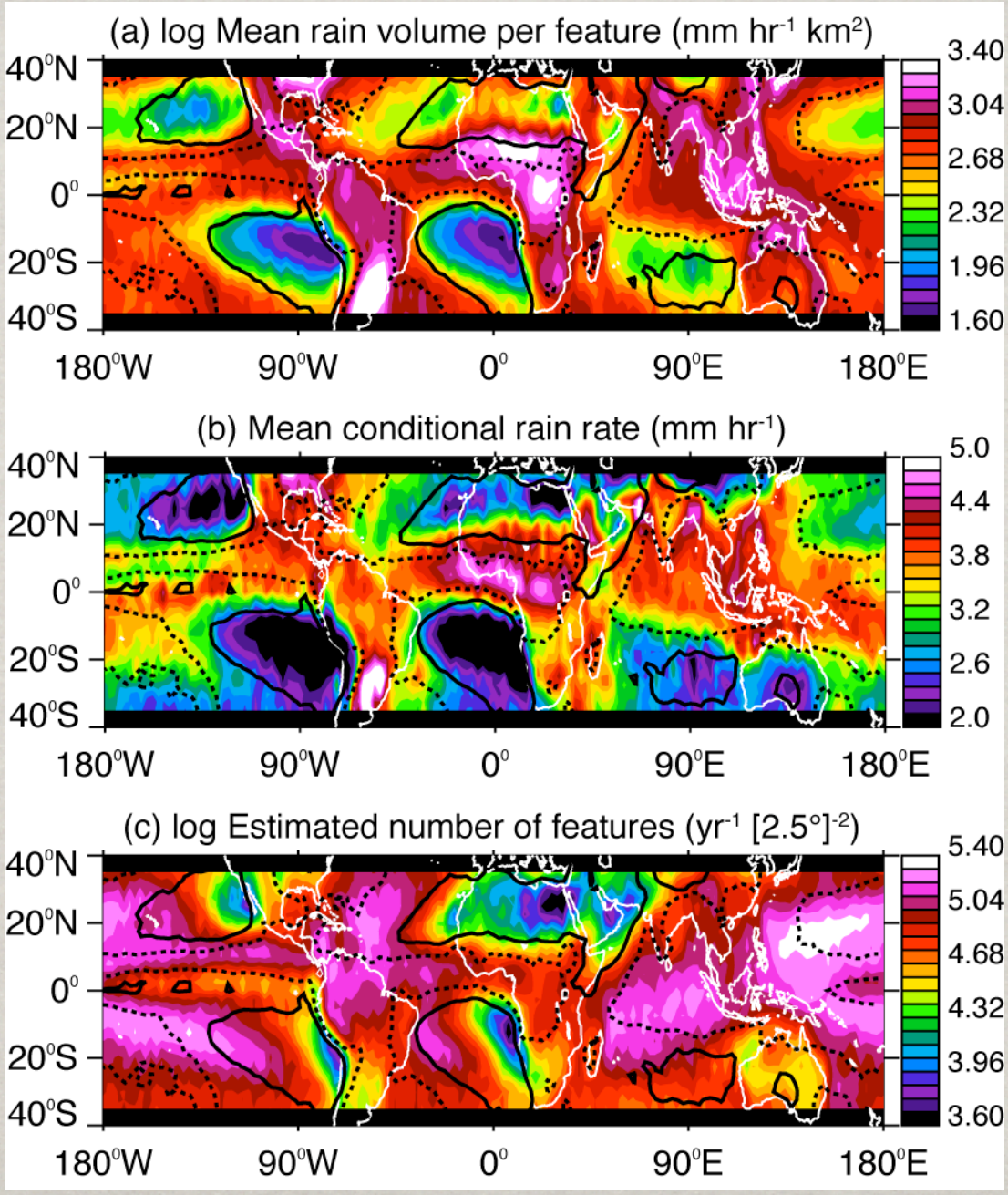
Rain volume per feature (mm hr^{-1} km^2)

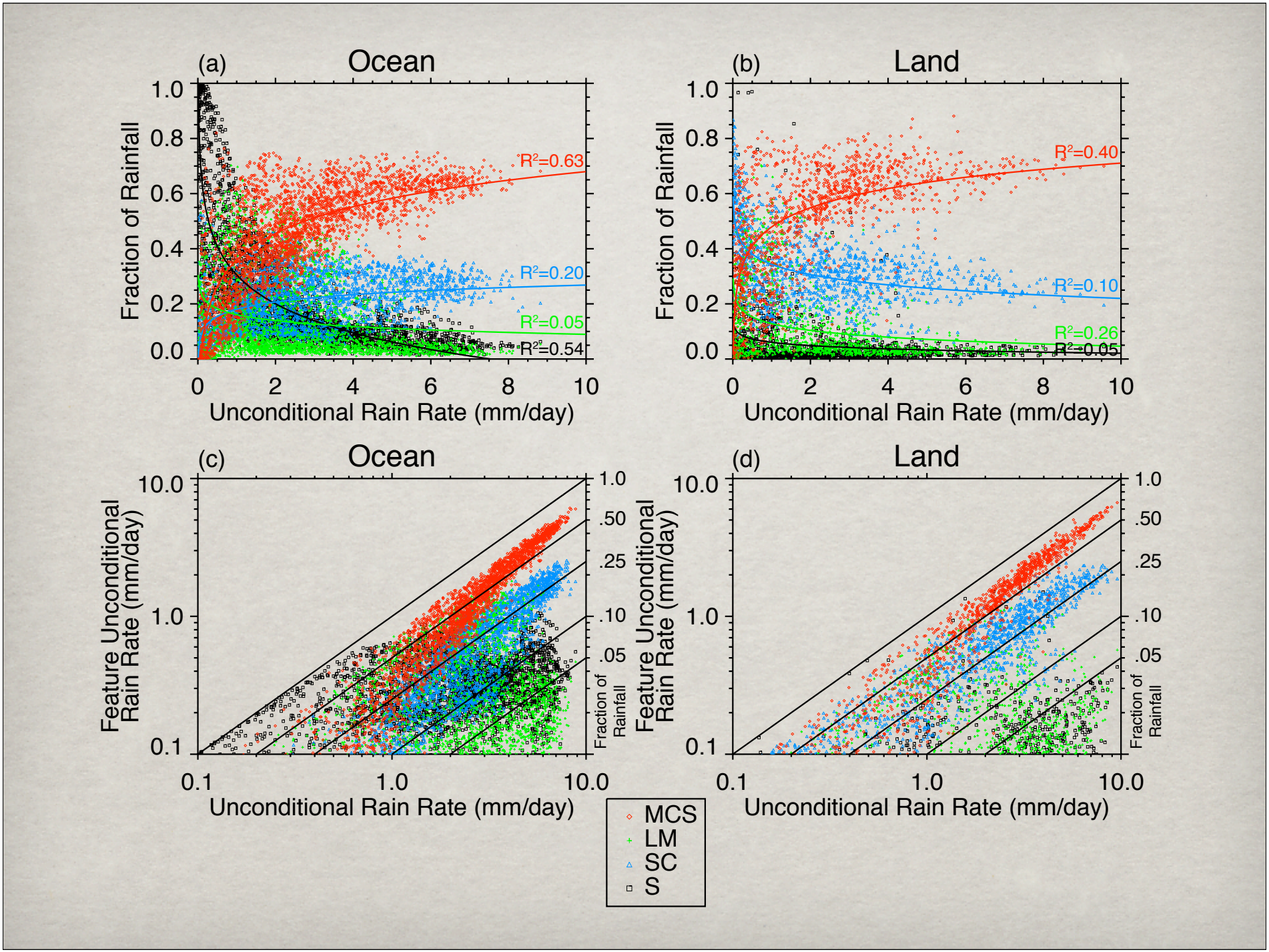



Fraction of number of features
Shallow
Small cold
Large mid-level
MCS
Ocean
0.6%
0.5%
20.2%
78.7%
Land
1.6%
0.8%
39.0%
58.5%

Fraction of rainfall stratiform



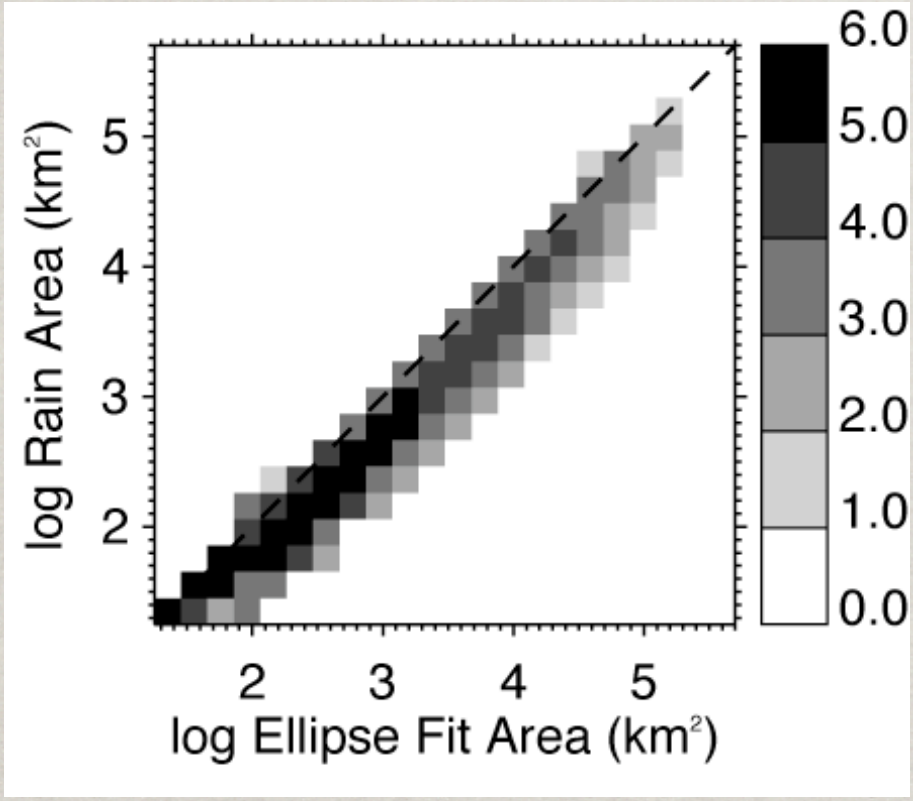

(a) log Mean rain volume per feature (mm hr-1 km2)
40°N
20°N
0°
20°S
40°S
180°W
90°W
0°
90°E
180°E
3.40
3.04
2.68
2.32
1.96
1.60
(b) Mean conditional rain rate (mm hr-1)
40°N
20°N
0°
20°S
40°S
180°W
90°W
0°
90°E
180°E
5.0
4.4
3.8
3.2
2.6
2.0
(c) log Estimated number of features (yr-1 [2.5°]-2)
40°N
20°N
0°
20°S
40°S
180°W
90°W
0°
90°E
180°E
5.40
5.04
4.68
4.32
3.96
3.60


(a)
Ocean
Fraction of Rainfall
Unconditional Rain Rate (mm/day)
R²=0.63
R²=0.20
R²=0.05
R²=0.54
(b)
Land
R²=0.40
R²=0.10
R²=0.26
R²=0.05
(c)
Ocean
Feature Unconditional Rain Rate (mm/day)
Fraction of Rainfall
(d)
Land
MCS
LM
SC
S

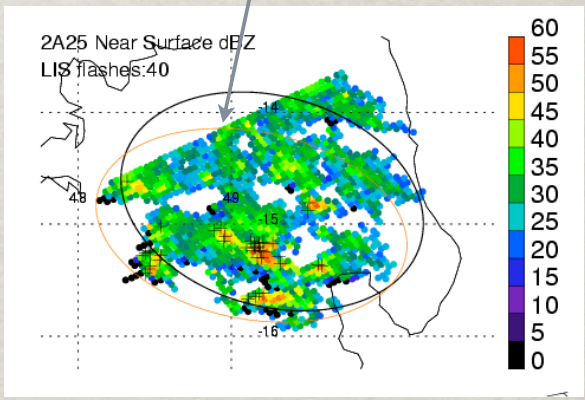
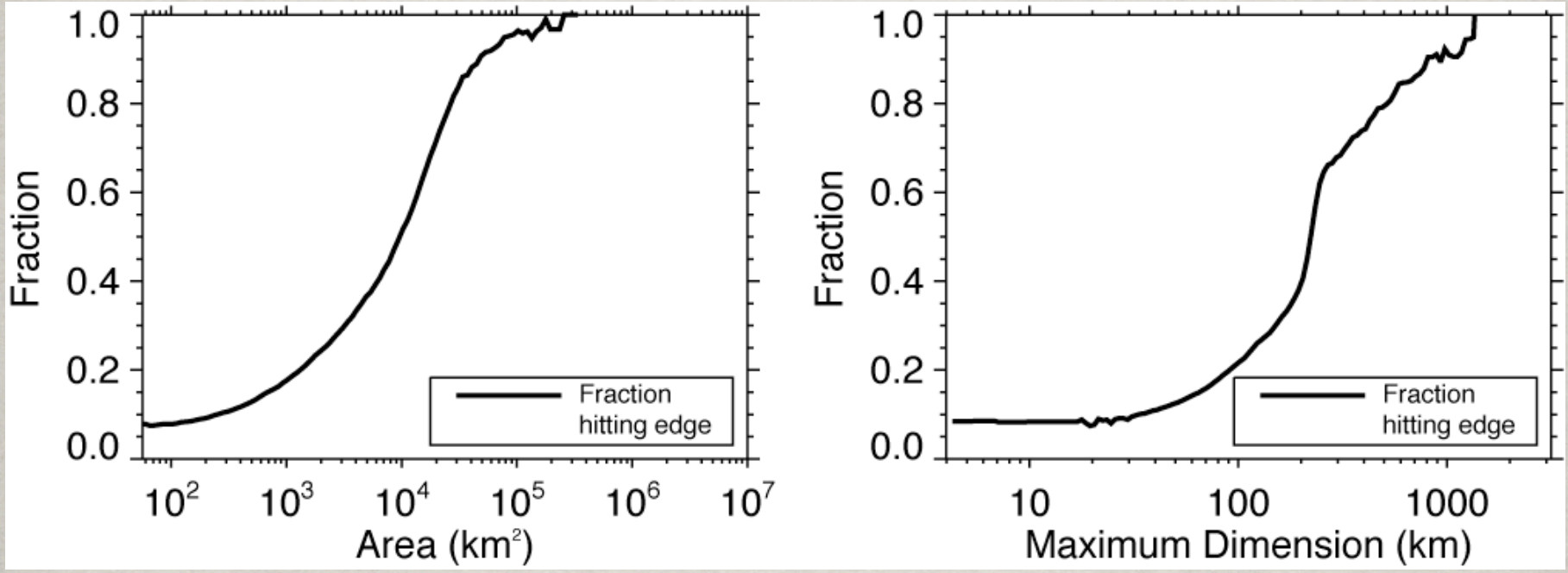
Summary

- TRMM precipitation feature database provides an excellent test bed for comparing with statistics from CRM and MMF-climate simulations
- Land-ocean differences in convective system populations and characteristics important in controlling rainfall rates and amounts
  - More convective rainfall, higher relative occurrence of heavier raining but less frequent features over land
- This study provides the framework to quantitatively compare observations and CRMs

Rain Area vs. Ellipse Fit Area



Edge of PR swath



Fraction of features hitting the edge of the PR swath