West African MCS Characteristics: A Climatological TRMM Perspective

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Statement of Research

Improve our understanding of the West African monsoon (WAM) and the complex system of components that make up the WAM with a focus on associated mesoscale phenomena. Analysis of mesoscale features through the comparison of convective property statistics allows the study of zonal and meridional variability across West Africa. Associating characteristics with African easterly waves (AEWs) can help in understanding mesoscale variability during synoptic events, and illuminate feedback mechanisms between spatial scales. Improved understanding of mesoscale characteristics and variability is useful for future simulation parameterizations and studies.

1. Introduction

The African continent remains an area of sparse observations, with little in the way of ground observational networks. A number of field campaigns have provided data for limited time periods (e.g. GATE, COPT-81, EPSAT, JET2000, AMMA/NAMMA), providing a number of opportunities for case studies and limited time period statistics. Satellites represent the only temporally and spatially consistent method for analysis. In particular the TRMM satellite platform offers a unique opportunity to study mesoscale phenomena in West Africa

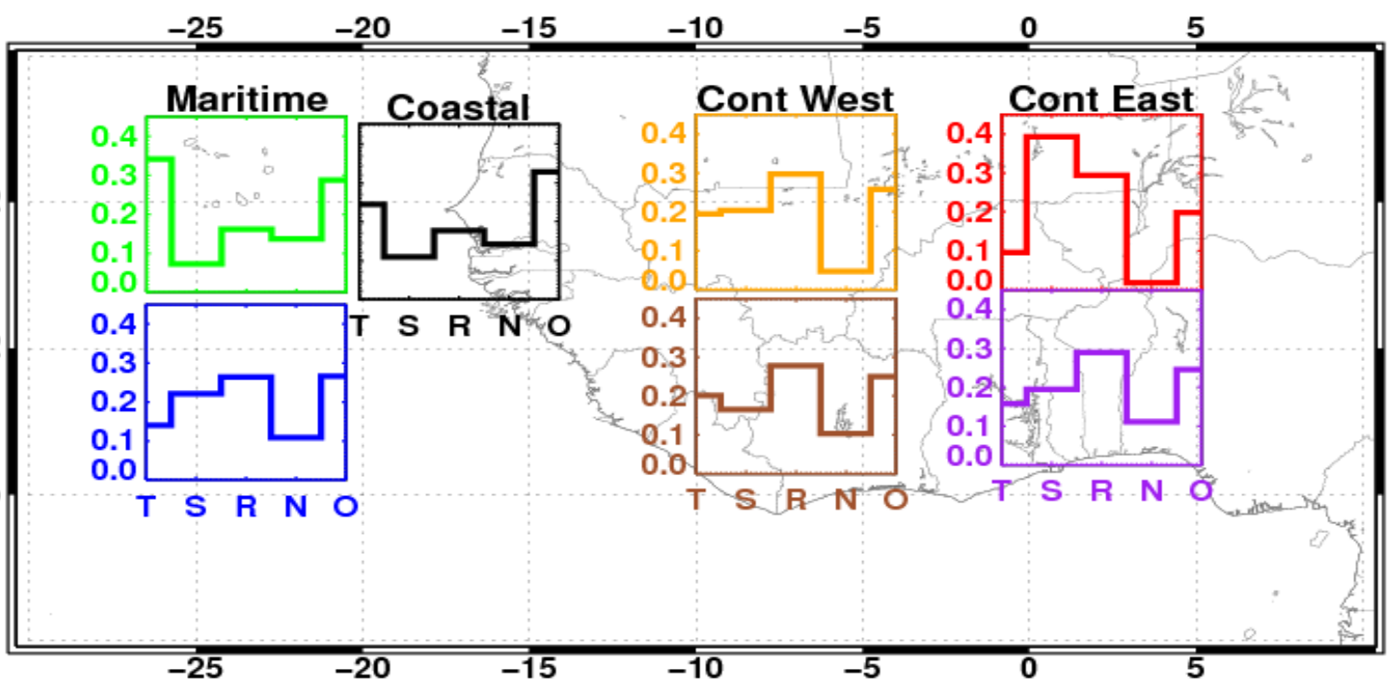
A great deal of variability in precipitation structure exists in West Africa. Model simulations generally do a poor job representing West African precipitation and features. Though it is well established that mesoscale convective systems (MCSs) are the primary contributors to precipitation, their characteristics over a longer time frame have not been studied in this region. Additionally, convective characteristics on the mesoscale are not fully understood as a function of the primary synoptic forcing component, African easterly waves.

2. Methodology

a. Seven 6° x 6° regions in West Africa were defined to compare zonal and meridional variability, along with convective characteristics in each region as a function of African easterly wave (AEW) phase. The University of Utah TRMM Precipitation Feature (PF) database (Liu et al. 2008) was employed to build a 13-year "climatology" (1998- 2010) of convective characteristics (V6 data).

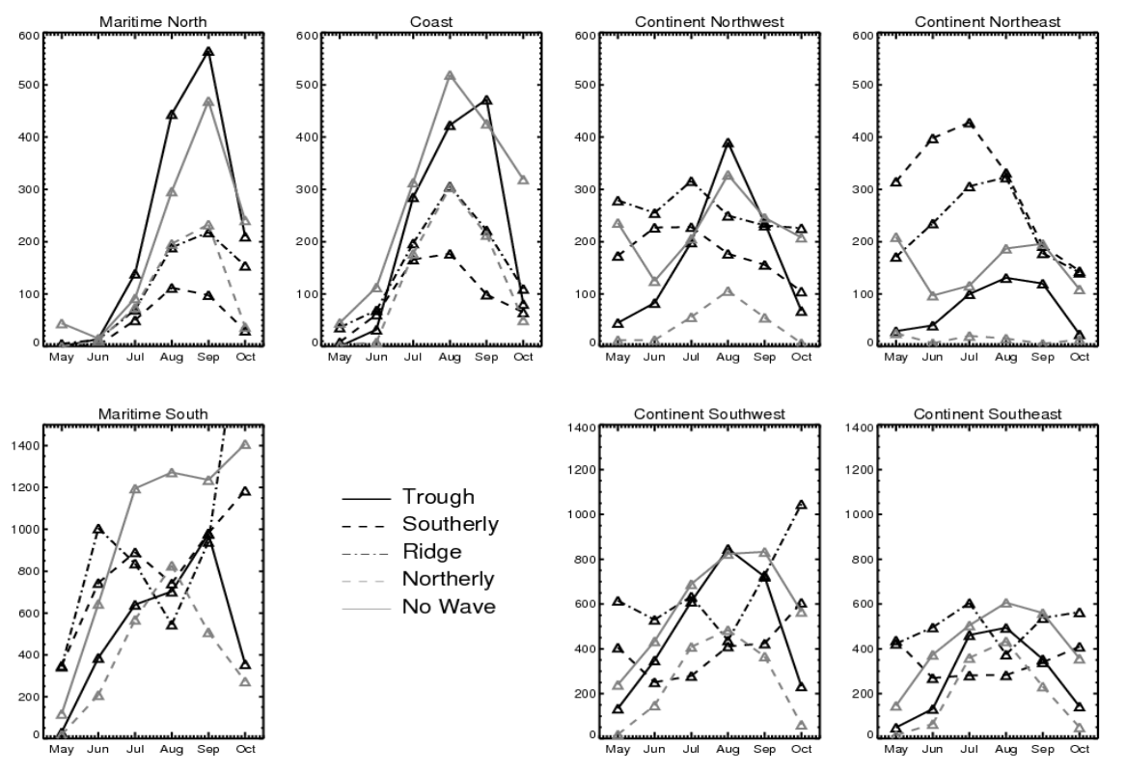
b. PFs were defined by contiguous TRMM precipitation radar (PR) pixels. Only systems larger than 75 km^2 and with at least one pixel > 30 dBZ were retained.

Fig. 1. Frequency of PF occurrence for each AEW phase (see Section 2) in each defined region.



T = Trough
S = Southerly
R = Ridge
N = Northerly
O = No AEW phase

Fig. 2. Monthly distribution of precipitation features associated with objectively identified AEW phase. Note different ordinate scales.



- Larger number of PFs identified in southern regions
- Evident peaks in boreal summer (monsoon) months

c. TRMM 3-D PR reflectivity, Microwave Imager (37- and 85-GHz PCT) and calculated stratiform fraction (from 2A23 product) were associated with each PF.

d. Ice and liquid water mass were calculated using reflectivity data and geographical location following Petersen et al. (2005).

e. AEW phases (Trough, Southerly, Ridge, Northerly, and No-Wave) were attained from ECMWF-Interim reanalysis U and V winds using the Berry et al. (2007) trough tracking algorithm, along with V wind information. PFs were categorized based on location with respect to regions identified as trough, southerly, ridge, and northerly AEW phases. If no AEW phase was identified, then the PF was identified as no-wave regime. Figures 3-4 show examples of this method.

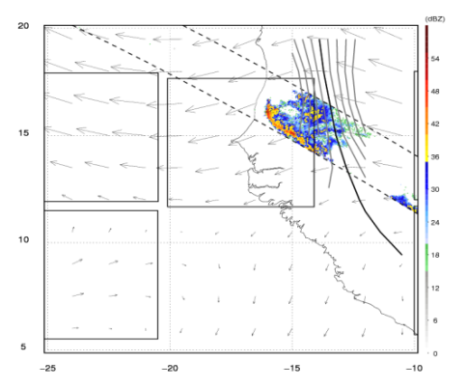


Fig. 3. TRMM overpass on 31 August 2006 depicting an example of objectively identified AEW trough phase associated PF.

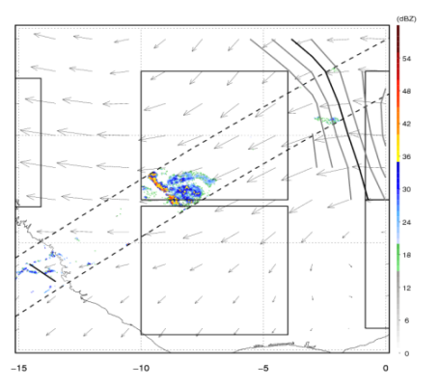


Fig. 4. TRMM overpass on 29 August 2006 depicting an example of objectively identified No-Wave associated PF.

References

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3.a. Results – Convective Characteristics

In general convective characteristics displayed greater variability between regions than between AEW phases. Distributions agreed with previous results highlighting differences between land and ocean. Mean profiles of vertical reflectivity displayed greater variability in the convective regions than the stratiform regions of PFs. Stronger profiles were observed inland, decreasing in strength westward into the Atlantic Ocean. This corresponded to higher storm top and 30-dBZ echo heights inland, decreasing westward.

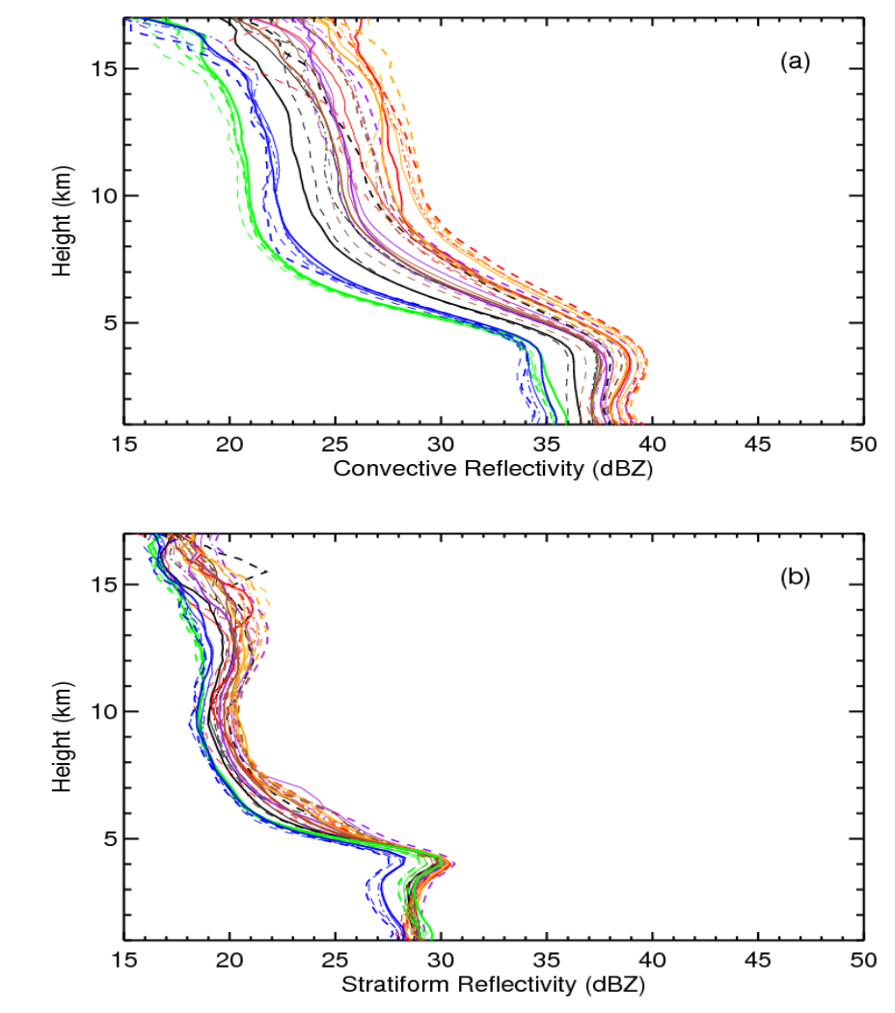


Fig. 5. Mean vertical profile of reflectivity for each region (see color coding in Fig. 1). AEW regimes are indicated by line type (see Fig. 2).

- Land profiles higher reflectivity throughout the vertical
- Larger reflectivity gradient above 5 km over ocean
- Evident brightband signature near 4.5 km
- Stratiform exhibited less variability between regions

Feature area increased moving eastward, though stratiform fractions tended slightly opposite, with greater fractions observed over ocean regions. Enhanced 85-GHz depressions were observed over land, another metric of stronger convection.

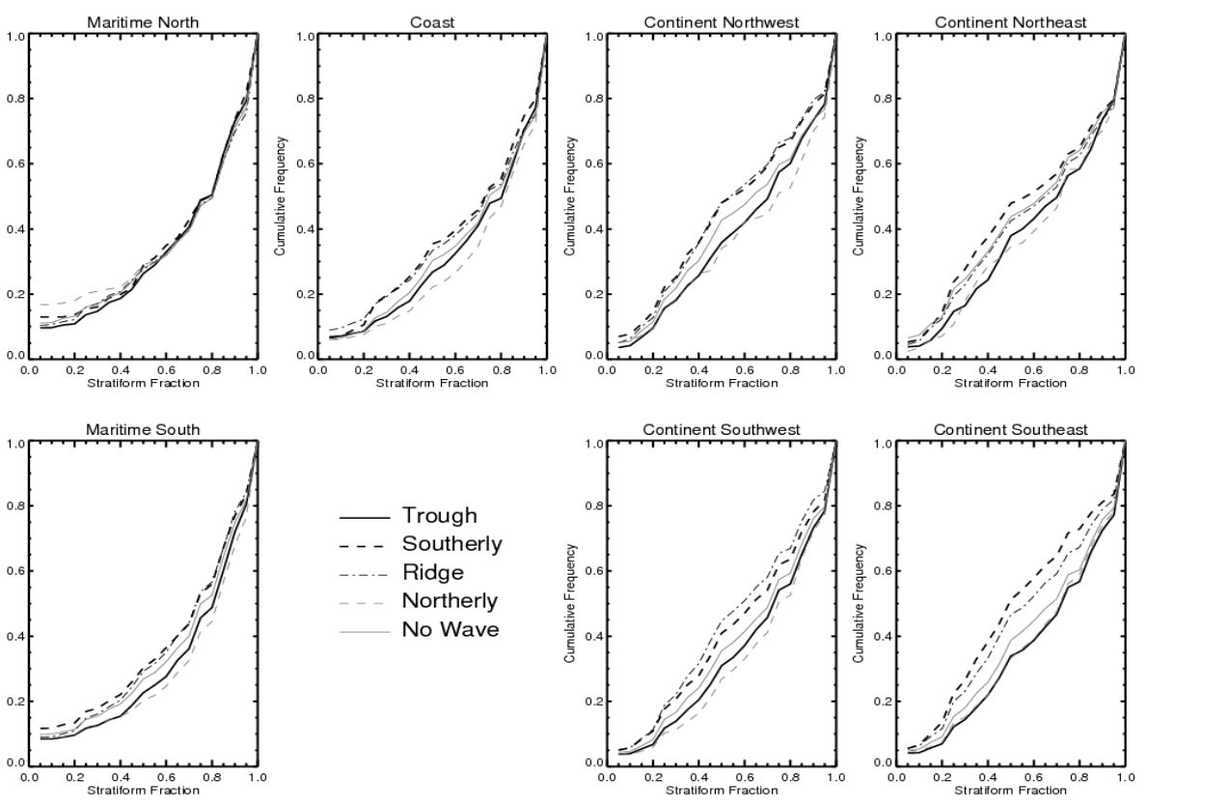


Fig. 6. Cumulative frequency of stratiform fraction (from TRMM algorithm) for each region and AEW phase.

- Largest variability of all convective characteristics between intra-region AEW phases
- Variability in distributions between regions
- Seasonal cycle of precipitation systems may affect southern continental regional variability

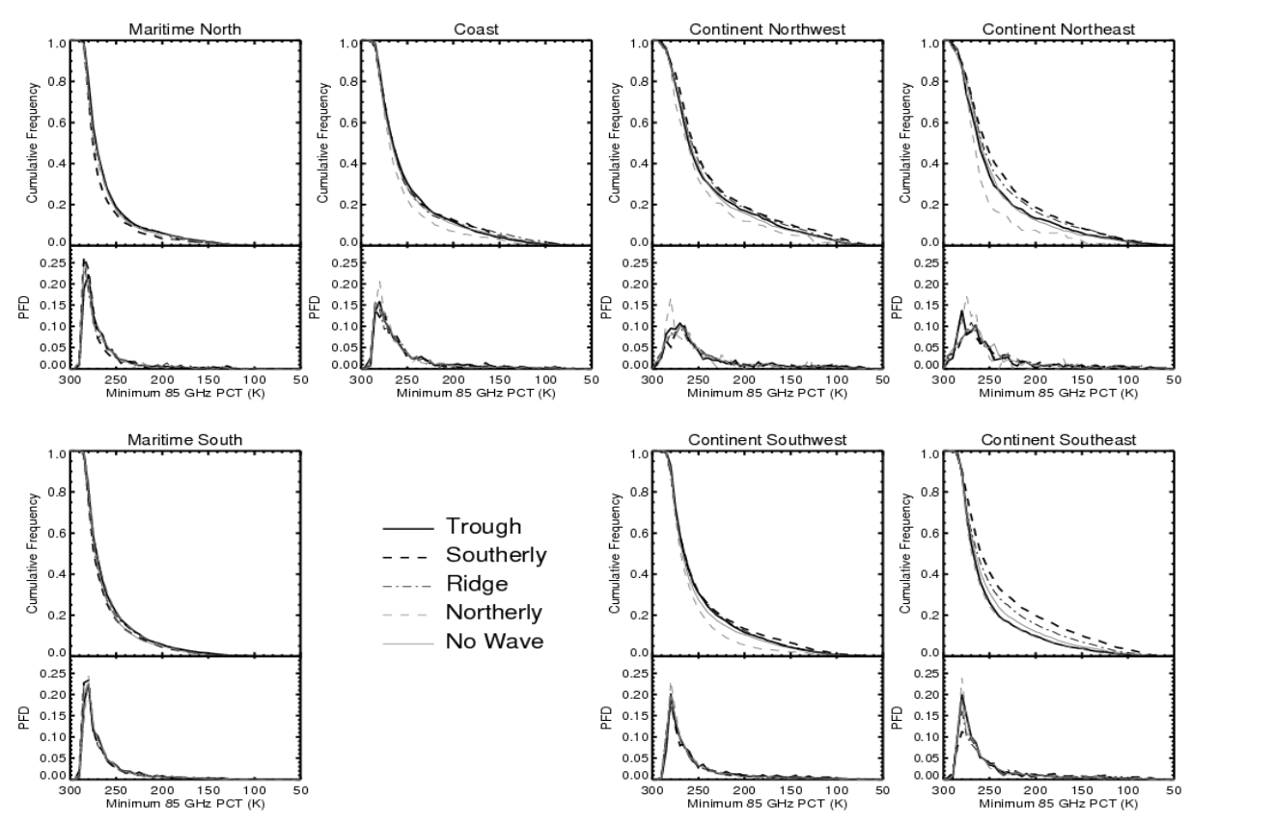
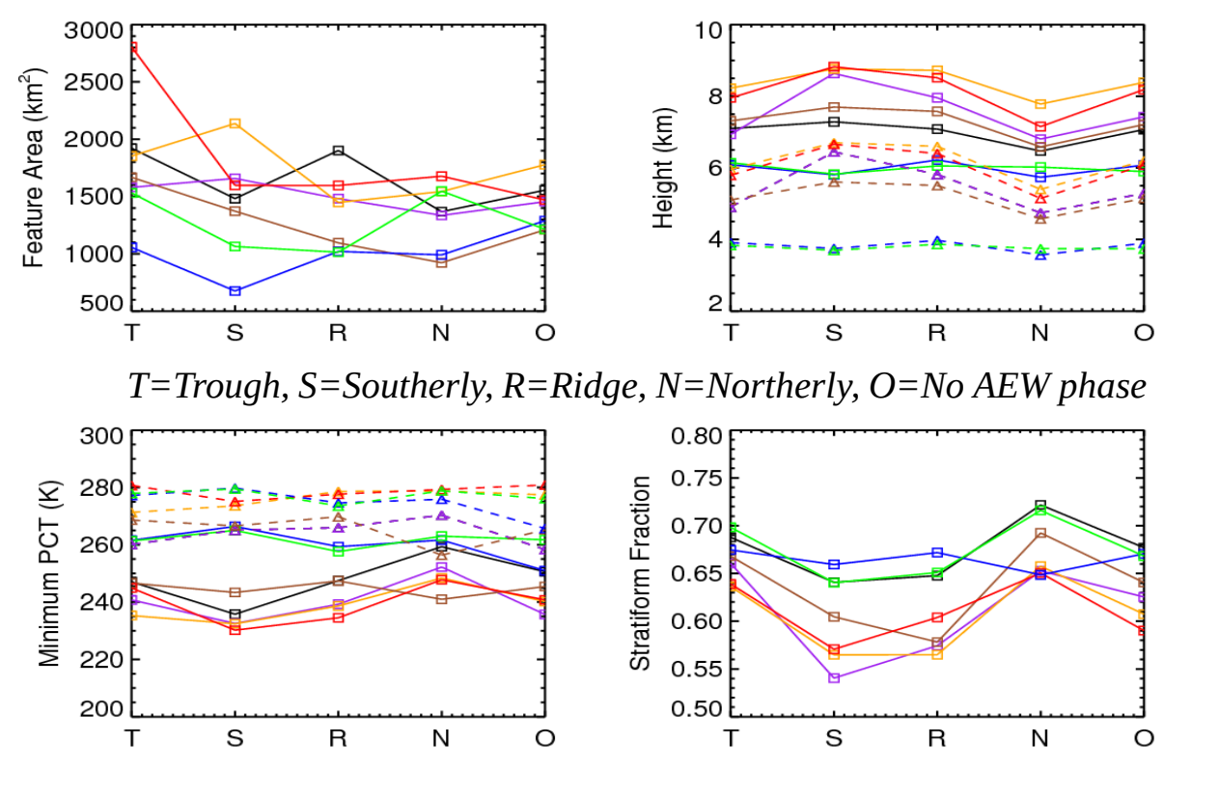


Fig. 7. Cumulative frequency of 85-GHz PCTs for each region and AEW phase.

- Larger 85-GHz depressions inland
- Variability in distributions between regions
- Greater spread in cumulative distributions observed in eastern continental regions

3.b. Results – Mean Values



T=Trough, S=Southerly, R=Ridge, N=Northerly, O=No AEW phase

Fig. 8. Mean convective characteristics of each regions by AEW regime. See Fig. 1 for color coding.

- Trough – widespread convection
- Southerly – isolated, intense convection
- Ridge – Similar to trough, but slightly stronger
- Northerly – decreased convective strength
- No Wave – Similar to southerly, more stratiform

3.c. Results – Microphysical Characteristics

Ice water content (IWC) was an order of magnitude greater over the continent than over the Atlantic, along with large spread between AEW phase regimes. Differences in liquid water content (LWC) were also observed, though to a lesser degree than IWC. Results indicated that ice microphysics become increasingly important moving inland.

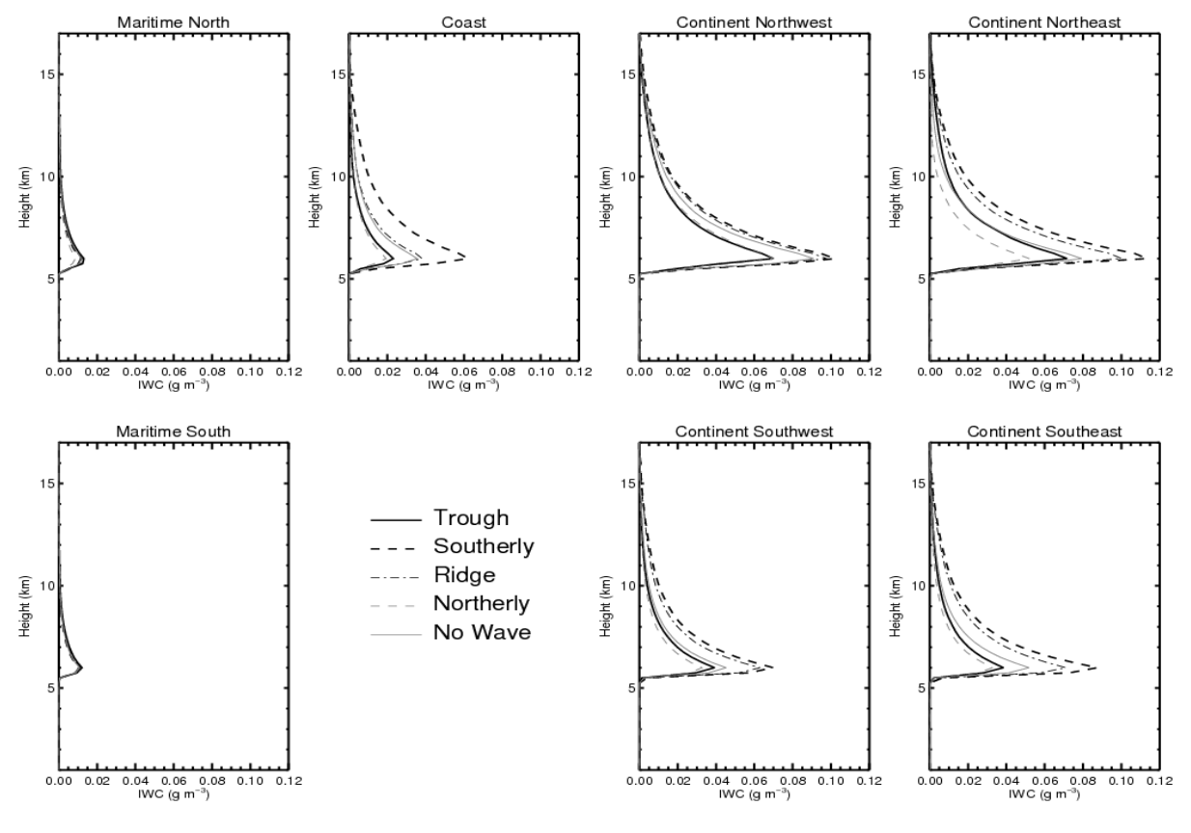


Fig. 9. Mean vertical profile of ice water content for each region and AEW phase.

- Land profiles exhibited larger IWC, greater AEW phase variability
- Corresponds with greater ice scattering signature observed in 85- and 37-GHz observations

IWP Fraction = (IWP/(IWP+LWP))

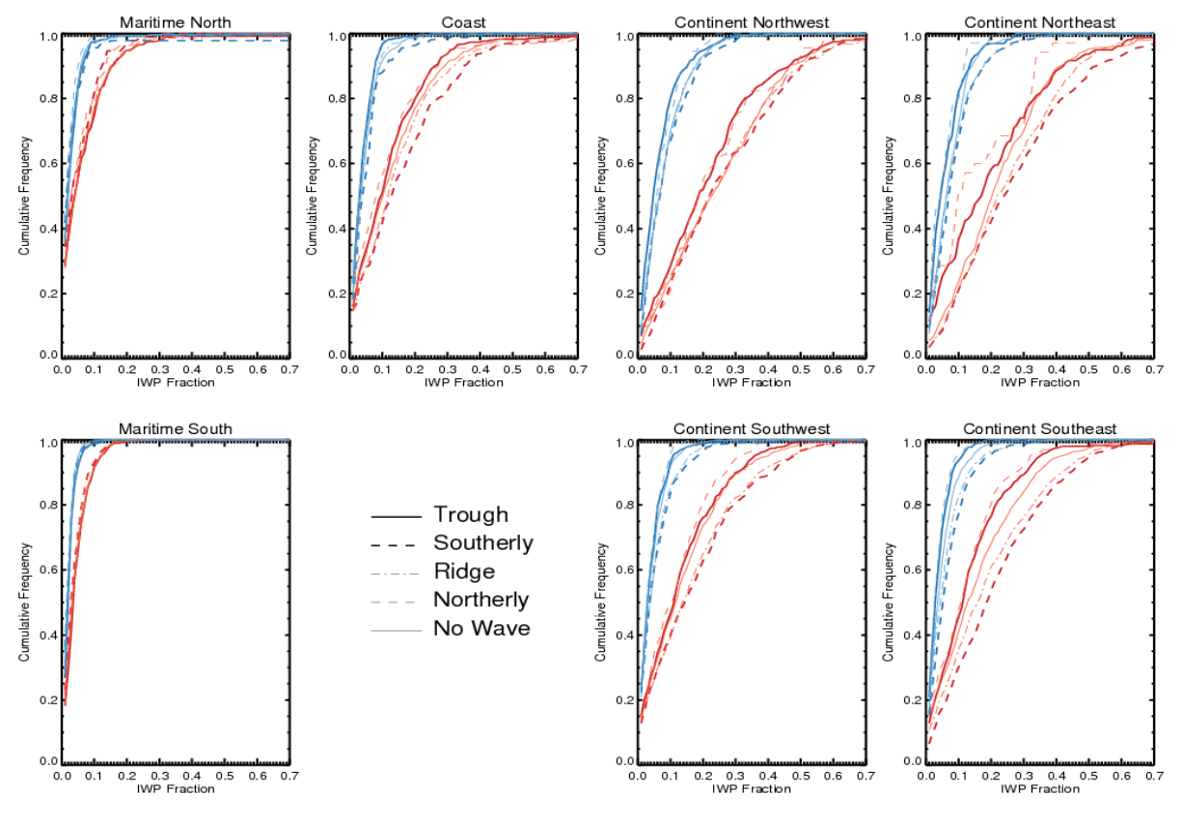


Fig. 10. Cumulative distribution of ice water content for each region and AEW phase.

Convective regions contributed the majority of ice water mass and nearly half liquid water mass.

LWP Fraction = (LWP/(IWP+LWP))

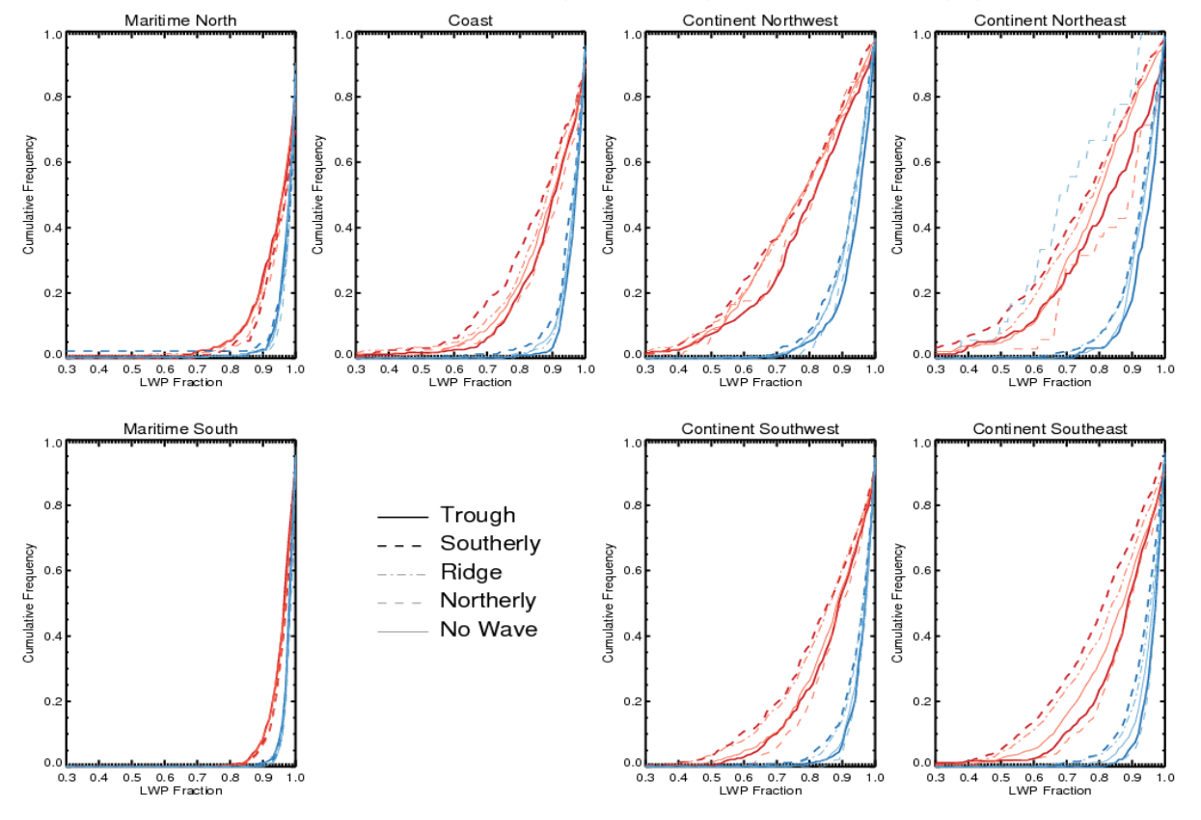


Fig. 11. Cumulative distribution of liquid water content for each region and AEW phase.

Warm-rain processes over ocean, with increasing ice microphysics inland. Ice precipitation processes appeared more important in northern regions.

4. Summary

Using 13 years of TRMM observations, a "climatology" was constructed for mesoscale convective systems over West Africa identified as precipitation features in the University of Utah Precipitation Feature Database. This is the first study over a longer time period (> 2-3 years) to categorize regional differences in meso-α and –β scale convective systems in West Africa. Additionally characteristics were divided by African easterly wave phase (and when no wave was present) using a novel combination of previous techniques. Major findings are listed below:

- Regional variability between convective characteristics was greater than between AEW phases
- No-wave characteristics were similar to AEW regime characteristics, indicating that environmental characteristics may be more important than AEWs to convective system strength as well as morphology
- Stronger vertical reflectivity profiles, taller echo top and 30-dBZ heights, larger ice scattering signatures (enhanced 85- and 37-GHz depressions), and ice water contents were observed over land than at the coast or over the Atlantic Ocean
- Stratiform fraction displayed large variability between AEW phases intra-region, which hints at differences in latent heating structure as a function of region
- Liquid water contents along with ice water and liquid water path fractions indicated a stronger warm rain signal in the southern regions, especially apparent over land
- Ice microphysics appeared to be more important at inland locations than the oceanic counterparts

Publication

Guy, N., and S. A. Rutledge, 2011: Regional comparison of West African convective characteristics: A TRMM-based Climatology. Submitted to *Quart. J. Roy. Meteor. Soc.*

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