Investigating Extreme Precipitation and Associated Cloud-Top Temperatures in Flash Flood Events over West Africa

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INTRODUCTION

Flash floods triggered by heavy rainfall are among the most destructive hydrometeorological hazards in West Africa, causing significant losses of life and infrastructure. However, forecasting these events remains challenging. Numerical weather prediction has limited skill in this region, due to challenges in simulating convective systems and the scarcity of ground observations. Geostationary satellites provide high-frequency, high-resolution cloud-top temperature data that contribute to improving the predictability of heavy precipitation and flash flood events.

OBJECTIVES

This study aims to:

- Assess whether flood and flash flood events across West Africa are associated with extreme precipitation.
- Examine the evolution of cloud-top temperature (CTT) before and during extreme precipitation associated with flash flood events.

METHODOLOGY

Datasets

Precipitation was obtained from the Integrated Multi-satellitE Retrievals for GPM (IMERG) Early Run, provided by NASA. CTT was derived from the 10.8 µm channel of the High Rate SEVIRI Level 1.5 Image Data – MSG-0°, provided by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT).

	Spatial Resolution	Temporal Resolution
IMERG – Early Run	0.1°	30 minutes
High Rate SEVIRI Level 1.5 Image Data – MSG-0°	0.03°	15 minutes

Flash Flood Events and Associated Precipitation

Daily precipitation records were compared with the 95th and 99th percentiles of rainy days over a 25-year period, and lists of flood and flash flood events across West Africa were compiled using event data from FloodList.com and EM-DAT International Disaster Database (https://www.emdat.be).

Cloud-Top Temperatures in Extreme Events

The relationship between precipitation on extreme days and CTT was assessed by identifying core pixels with daily precipitation exceeding the 95th percentile of a 25-year record. Neighboring pixels were then included within the spatial decorrelation length.

RESULTS

Flood and Flash Flood Events and Associated Precipitation

Flash Flood Events and Associated Daily Precipitation (West Africa)

Country	Date	Latitude	Longitude	Precipitation (mm/day)	95th Percentile (mm/day)	99th Percentile (mm/day)
Côte d'Ivoire	19/06/2018	5.35	-4.05	55.42	24.30	52.30
Cote d'Ivoire	25/06/2020	5.35	-4.25	46.01	26.79	56.94
Ghana	10/10/2020	5.65	-0.15	34.50	22.06	48.01
Ghana	07/03/2023	5.65	-0.15	34.23	22.06	48.01
Guinea	18/05/2019	9.55	-13.65	52.36	46.51	80.90
Liberia	17/07/2018	6.45	-10.75	65.29	43.80	80.14
Nigeria	14/06/2020	4.55	7.75	64.34	42.66	70.35
Nigeria	18/06/2020	6.45	3.25	98.98	30.12	60.32
Nigeria	28/06/2020	6.55	3.55	111.11	29.40	59.97
Nigeria	12/09/2021	8.95	7.45	54.17	24.09	45.53
Sierra Leone	02/08/2019	8.49	-13.22	77.25	37.83	67.02

Flood Events and Associated Daily Precipitation (Ghana)

Region	Date	Latitude	Longitude	Precipitation (mm/day)	95th Percentile (mm/day)	99th Percentile (mm/day)	10-day Precip (mm)
Accra	05/06/2014	5.55	-0.20	61.36	21.50	48.22	132.53
Jomoro	10/07/2014	5.15	-2.65	1.83*	30.48	58.99	133.00
Accra	03/06/2015	5.55	-0.25	56.12	21.05	46.80	189.50
Accra	09/06/2016	5.55	-0.20	36.42	21.50	48.22	93.61
Accra	18/06/2018	5.55	-0.20	57.12	21.50	48.22	81.08
Kumasi	28/06/2018	6.75	-1.65	32.21	19.80	36.18	67.42
Accra	07/04/2019	5.55	-0.25	63.27	21.05	46.80	86.85
Obuasi Municipality	15/05/2019	6.15	-1.75	20.81	23.77	45.06	73.58
Agbogba	28/10/2019	5.69	-0.20	66.87	22.00	48.21	96.21
Asokwa	24/9/2020	6.25	-1.50	43.53	22.47	44.94	61.64
Kumasi	24/06/2021	6.65	-1.65	15.43	20.15	37.05	99.44
Ahanta West Municipal District	21/6/2023	4.85	-2.05	43.67	27.09	62.76	86.87

Precipitation exceeded the 99th percentile of rainy days

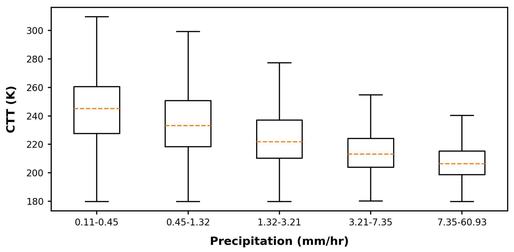
Precipitation between the 95th and 99th percentiles of rainy days

Consecutive rainy days within the 10 days prior to the event, with at least one day exceeding the 95th percentile

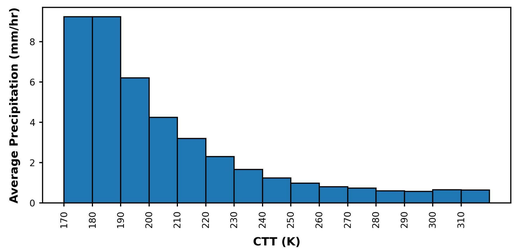
* Near-extreme precipitation (≈99th percentile) occurred five days prior to the event

Cloud-Top Temperatures in Extreme Events

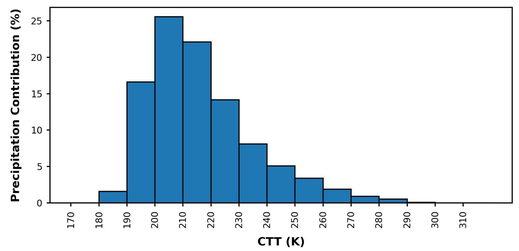
CTT Distribution by Precipitation



Average Precipitation across CTT Ranges



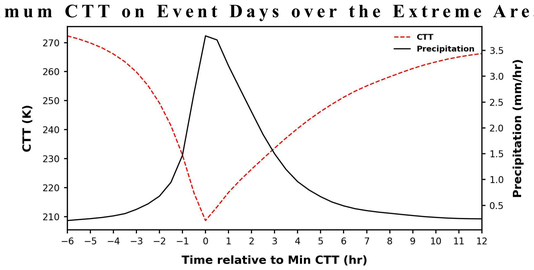
Precipitation Contribution across CTT Ranges



Lead–Lag Correlations between Half-Hourly Precipitation and Mean and Minimum CTTs During and before Precipitation

	At Precipitation Time	30 min before	60 min before	90 min before
Mean CTT	-0.53	-0.50	-0.43	-0.34
Minimum CTT	-0.53	-0.50	-0.44	-0.35

CTT and Precipitation Relative to the Time of Minimum CTT on Event Days over the Extreme Area



CONCLUSIONS

- Flash flood events across West Africa are closely associated with extreme precipitation, characterized by daily rainfall exceeding high-percentile thresholds.
- Precipitation intensity exhibits a robust negative relationship with CTT, with the strongest correlation occurring during precipitation rather than at earlier lead times. For extreme pixels, the most intense precipitation occurs at the time of minimum CTT on the event days.
- During extreme events, most precipitation occurs when CTTs are within the 190–230 K range.

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