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学位論文題名	Long-term and recent changes in the spatial characteristics of extreme rainfall in India from the perspective of aerosol and atmospheric dynamics （エアロゾルと大気ダイナミクスからみたインドにおける極端降水の空間分布特性の長期及び近年の変化）
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【論文の内容の要旨】

Climate variability at regional and sub-regional scales is highly pronounced in the tropics and plays an important role in the spatial distribution of rainfall. Recently, intensified and widespread rainfall events have influenced agriculture activity and restrained the economic situation in the Asian region. Current investigations revealed an increase in extreme rainfall events (EREs) over the tropics and Indian region, which could cause flood-like situations. This thesis focuses primarily on EREs because of the crucial challenges concerning them. Additionally, we investigated the impact of dynamical and anthropogenic changes on EREs.

The spatial scales of EREs over Asia and India have not been determined. We investigated EREs under various spatial ranges using a proposed precipitation system-based approach (PSA). Understanding the spatial scale of ERE systems is crucial to elucidate connected atmospheric dynamics, which influence regional and seasonal rainfall.

We examined the spatial characteristics of ERE systems over the Asian region in recent decades (2001–2020) using the PSA over the GPM (IMERG) satellite-observed rainfall (>99th percentile). ERE characteristics differ markedly across the land, ocean, coasts, and maritime continents. The annual cycle of ERE systems showed a higher frequency during the summer monsoon (June–September), followed by the post-monsoon (October–December) season. Further, we categorized the spatial sizes of the ERE systems into sporadic, intermediate, and massive ERE rainfall systems, which correspond to thunderstorm activity, mesoscale, and

synoptic-scale systems, respectively. The sporadic, intermediate, and massive EREs were higher over the mountains, land-ocean and mountain-land, and ocean regions, respectively.

A station-based gridded and station-satellite-blended rainfall dataset from the meteorological department of India and CHIRPS was used to examine the long-term (50 years; 1951–2000) and recent (38 years; 1981–2018) variations in rainfall characteristics over India. Long-term variations in ERE characteristics revealed that the sporadic rainfall grid contributes to 42% of all ERE grids, and the sporadic ERE frequency increases in the long term. The long-term trend of intermediate EREs does not increase, whereas massive EREs increase quite sharply; however, both these EREs are intensifying. The past 38 years have shown a reverse in the trends of ERE characteristics. The frequency and intensity of intermediate and massive EREs have decreased; however, massive ERE systems are broadening.

The massive ERE (MERE) systems can potentially cause hazardous impacts over a widespread area. Given the current climate change scenario, increase in the size of these EREs is an impending threat. Therefore, in the second part, we investigated the 38-year climatology of MEREs and their dynamics using the ERA5 reanalysis dataset. We computed the high-frequency cyclonic circulation by applying a band-pass filter of 2–20 days on the lower atmospheric winds at 850 hPa. We found that cyclonic or non-cyclonic circulations bring most MEREs over central India. Among them, 60%–65% of the MEREs are due to strong cyclonic circulations, which create a low-pressure area near the adjacent ocean. In the last 38 years, the MEREs associated with the cyclonic circulations have increased, and the non-cyclonic circulation has decreased. In addition, the size of MEREs, which are associated with cyclonic circulations, is broadening. Further, we found that this increase is associated with strengthening winds and moisture transport corresponding to cyclonic circulation in the central Indian region.

In recent years, the increase in urbanization and anthropogenic activities has played an important role in changing the atmospheric dynamics and ERE characteristics. The atmospheric circulation is different in the presence of aerosol (pristine /no-aerosols) environments. In the third part of the thesis, we investigated spatial and temporal modulation of aerosol species using the CAMS reanalysis and Moderate Resolution Imaging Spectroradiometer satellite observations from 2003–2019 and their influence on the ERE characteristics.

We found that a low-frequency (25–90 days) intraseasonal monsoon oscillation (MISO) modulates the aerosol's spatial-temporal distribution. In the eight MISO phases, southwesterly strengthening/weakening were responsible for the spatial distribution of aerosols through transport. The climatological spatial distribution of the aerosol species showed long-range transport of sea salt from the Arabian Sea and dust from the desert regions of the Arabian Peninsula to the Indian landmass.

Further, we analyzed how the modulation of aerosol by MISO influences the EREs. For this, we evaluated the high and low amounts of aerosols observed during the MISO phases in two different scenarios. We found that in the presence of a high

(less) amount of aerosols in active/active-break (break/break-active) transition phases, the frequency of EREs was less (high). However, the mean rainfall was higher in the initial active phases of MISO. Additionally, we investigated the modulation of aerosol, atmospheric dynamics, and ERE characteristics in the summer monsoon season by the MISO.

This thesis proposes a new method to compute the spatial extent of EREs and their interaction with the high-frequency and low-frequency atmospheric dynamics. Additionally, we determined the significant role of aerosols in modulating EREs.