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Relating rainfall characteristics to cloud top temperatures at different scales

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Extreme rainfall from mesoscale convective systems (MCS) poses a threat to lives and livelihoods of the West African population through increasingly frequent devastating flooding and loss of crops. However, despite the significant impact of such extreme events, the dominant processes favouring their occurrence are still under debate.
In the data-sparse West African region, rainfall radar data from the Tropical Rainfall Measuring Mission (TRMM) gives invaluable information on the distribution and frequency of extreme rainfall. The TRMM 2A25 product provides a 15-year dataset of snapshots of surface rainfall from 2-4 overpasses per day. Whilst this sampling captures the overall rainfall characteristics, it is neither long nor frequent enough to diagnose changes in MCS properties, which may be linked to the trend towards rainfall intensification in the region. On the other hand, Meteosat geostationary satellites provide long-term sub-hourly records of cloud top temperatures, raising the possibility of combining these with the high-quality rainfall data from TRMM.
In this study, we relate TRMM 2A25 rainfall to Meteosat Second Generation (MSG) cloud top temperatures, which are available from 2004 at 15 minutes intervals, to get a more detailed picture of the structure of intense rainfall within the life cycle of MCS. We find TRMM rainfall intensities within an MCS to be strongly coupled with MSG cloud top temperatures: the probability for extreme rainfall increases from <10% for minimum temperatures warmer than -40°C to over 70% when temperatures drop below -70°C, confirming the potential in analysing cloud-top temperatures as a proxy for extreme rain.
The sheer size of MCS raises the question which scales of sub-cloud structures are more likely to be associated with extreme rain than others. In the end, this information could help to associate scale changes in cloud top temperatures with processes that affect the probability of extreme rain.
We use 2D continuous wavelets to decompose cloud top temperatures into power spectra at scales between 15 and 200km. From these, cloud sub-structures are identified as circular areas of respective scale with local power maxima in their centre. These areas are then mapped onto coinciding TRMM rainfall, allowing us to assign rainfall fields to sub-cloud features of different scales.
We find a higher probability for extreme rainfall for cloud features above a scale of 30km, with features ∼100km contributing most to the number of extreme rainfall pixels. Over the average diurnal cycle, the number of smaller cloud features between 15-60km shows an increase between 15 – 1700UTC, gradually developing into larger ones. The maximum of extreme rainfall pixels around 1900UTC coincides with a peak for scales ∼100km, suggesting a dominant role of these scales for intense rain for the analysed cloud type.
Our results demonstrate the suitability of 2D wavelet decomposition for the analysis of sub-cloud structures and their relation to rainfall characteristics, and help us to understand long-term changes in the properties of MCS.