Observation of different multifractal phase transitions over three typhoon events

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Rainfall is extremely variable in both space and time, which makes its analysis complex. A widely used framework to properly handle these features is Universal Multifractals (UM), which is a physically based and mathematically robust framework. It relies on three parameters, meaning it is parsimonious. Two types of multifractal phase transitions can affect the analysis of a series: (i) the divergence of moments, which is related to the singular limit of the underlying cascade process at small scales and notably explains the power law fall-off observed on numerous geophysical fields, (ii) sampling limitations, which is related to the fact that great moments cannot be observed on finite series.

This study employs UM to analyse the time series of rainfall intensities observed by the Parsival2 disdrometer at the 10-second resolution from three distinct typhoons over the period of July to October 2022, revealing differences and limitations in their statistical characteristics. It enables us to illustrate the two previously mentioned concepts of divergence of moments and sampling limitations and their impact on the analysis of rainfall data.

The analysis of typhoon Hinnamnor exhibited limitations due to the sampling dimension, indicating that the current data length was insufficient to capture the multifractal nature of the rainfall events for large moments, reducing the robustness of the analysis for moments greater than 5.43. It reflects sampling limitations, leading to a constrained understanding of extreme events.

For typhoon Nalgae, our analysis highlighted the occurrence of divergence of moments, i.e. a limitation associated with a critical moment. As higher-order moments were calculated, we observed statistical values tending towards infinity, suggesting that extreme rainfall events significantly influenced this typhoon and pointing out the inadequacy of traditional statistical methods in such scenarios. Such multifractal phase transition is seldom observed on individual series, highlighting the interest of studying this typhoon series.

Finally, the analysis of the typhoon Nesat presented a behavior affected by both multifractal phase transitions resulting in a more complex interpretation.

Our findings provide new insights into the multifractal analysis of typhoon rainfall intensities,
emphasising the importance of considering multifractal theory and its associated phase transitions when dealing with natural phenomenon data. These discoveries lay a crucial methodological foundation for more accurate prediction and response to extreme weather events. In case of rainfall, it then has some hydrological consequences notably in terms of stormwater management or optimization of dams for hydraulic production.