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Analysis on the Characteristics of Extreme Long Life Cycle Tropical Cyclone "Freddy" and the Causes of Heavy Rainfall

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Using multi-source global station and grid monitoring data, FY-2H satellite, and ERA5 reanalysis data, the life history and precipitation characteristics of tropical cyclone "Freddy" as well as the causes of heavy precipitation in southern Mozambique were analyzed. The results show that "Freddy" had a lifespan of 35.5 days which made it the longest lived tropical cyclone in the world, as well as the widest latitude-crossing TC in the southern hemisphere. The extreme long life cycle of "Freddy" was related to favorable large-scale circulation conditions. The strong and sustained subtropical high pressure system made "Freddy" moving westward over the Southern Indian Ocean stably, without the opportunity to combine with the mid latitude trough or cold air which may cause the path turning, intensity weakening, or transformation. After the generation of "Freddy", more than 70% of its life time was over the sea, and the surrounding SST was generally abnormally high, which provided favorable conditions for the development or maintenance of TC intensity. Especially, the SST within the Mozambique Strait remained above 28 □, providing excellent underlying conditions for the enhancement of TC intensity, allowing "Freddy" to develop and strengthen rapidly twice after experiencing intensity weakening caused by landfall. The combined influence of favorable circulation conditions and warm sea surface temperature led to the extreme long life of "Freddy".

"Freddy" made three landfall, bringing sustained heavy precipitation and severe floods to countries in Southeastern Africa. Especially in the southern part of Mozambique, precipitation had characteristics such as long duration, concentrated areas, and large accumulated amount. After landing in Mozambique, "Freddy" was located in a saddle field, leading to weakened steering airflow. Combined with high-level divergence and sustained transportation of warm and humid air by low-level jet, the large-scale circulation system provided favorable background conditions for the slow movement and maintenance of tropical cyclone. The development of low-level convergence and vorticity bands in lower troposphere, as well as strong and sustained water vapor transport, led to the persistence of heavy rainfall in Mozambique. The invasion of cold air induced the formation of a pseudo equivalent potential temperature high-gradient zone in southern Mozambique, and the cold air in the middle layer enhanced atmospheric instability, which was conducive to the development of convection. The southern part of Mozambique was continuously affected by several mesoscale convective systems (MCSs), which not only improved precipitation efficiency but also prolonged the duration of precipitation. The evolution of MCSs had obvious diurnal variation characteristics, with its rapid development and maturity stages

almost concentrating in the afternoon to the earlier evening of local time. The increase in low-level wind speed promoted the enhancement of both water vapor and energy, and under the above conditions, the convergence of tropical cyclone wind direction and wind speed triggered the generation of MCSs continuously.