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A Deep Learning Model for Tropical Cyclone Center Localization Based on SAR Imagery

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Tropical cyclones (TCs) are natural disasters originating over tropical or subtropical oceans. Their landfall is generally accompanied by extensive high winds and persistent precipitation, causing severe economic losses and human casualties yearly. Consequently, conducting effective TC landfall intensity forecasts for disaster risk reduction is imperative. The calm center of a TC, known as the TC eye, serves as a vital indicator of its intensity. Hence, precisely locating TC centers is crucial for determining TC intensity. In this study, a deep-learning model was developed to extract TC centers from satellite remote-sensing images automatically.
Space-borne synthetic aperture radar (SAR) imagery plays a critical role in monitoring natural hazards owing to its high spatial resolution, wide coverage, and day-night imaging capabilities. A total of 110 Sentinel SAR images spanning from 2016 to 2019 were used for TC center localization in this paper. They were acquired in interferometric-wide (IW) mode with a pixel size of 10 m and extra-wide (EW) mode with a pixel size of 40 m. They were resampled by spatial averaging to maintain the same pixel size of 80 m. Additionally, we manually annotated the central area of tropical cyclone images as ground truth data.
For the dataset, we initially divided 110 SAR images and the corresponding truth data into training, validation, and testing sets in an 8:1:1 ratio. Subsequently, we partitioned the SAR images into 256 × 256 pixel-sized slices as the model inputs. 32151/4611/3900 samples were extracted as the training/validation/testing dataset. Considering the target samples containing the center position are far less than compared background samples in TCs, we retained all center-containing samples and randomly selected 1.2 times the number of background samples for each image. Consequently, we obtained a final dataset of 2388/257/245 samples for training, validation, and testing.
As is known, deep learning technology excels in learning non-linear relationships and is good at automatically extracting intricate patterns from SAR imagery. The Res-UNet, a U-Net-like model with the weighted attention mechanism and the skip connection scheme that has been proven effective in solving the problem of contrast reduction caused by signal interference, was ultimately determined as the deep learning model for the automatic positioning of tropical cyclone centers in our study.
We calculated the centroid of the central region and compared the model results with ground truth. Our model outputs agreed well with the visually located TC center with a mean intersection over union (IOU) and a mean TC center location error of 0.71/0.70/0.67 and 3.59/2.24/2.20 km for

the training/validation/testing dataset. Moreover, our model greatly simplifies the complexity of traditional methods such as using spiral rainbands and background wind fields for center positioning. At the same time, our method can not only obtain the position of the TC center but also extract the central area, thereby obtaining the morphological characteristics of TCs, which is conducive to better monitoring and intensity determination of TC.