Kilometer-scale modeling better reflects the relationship between land and precipitation

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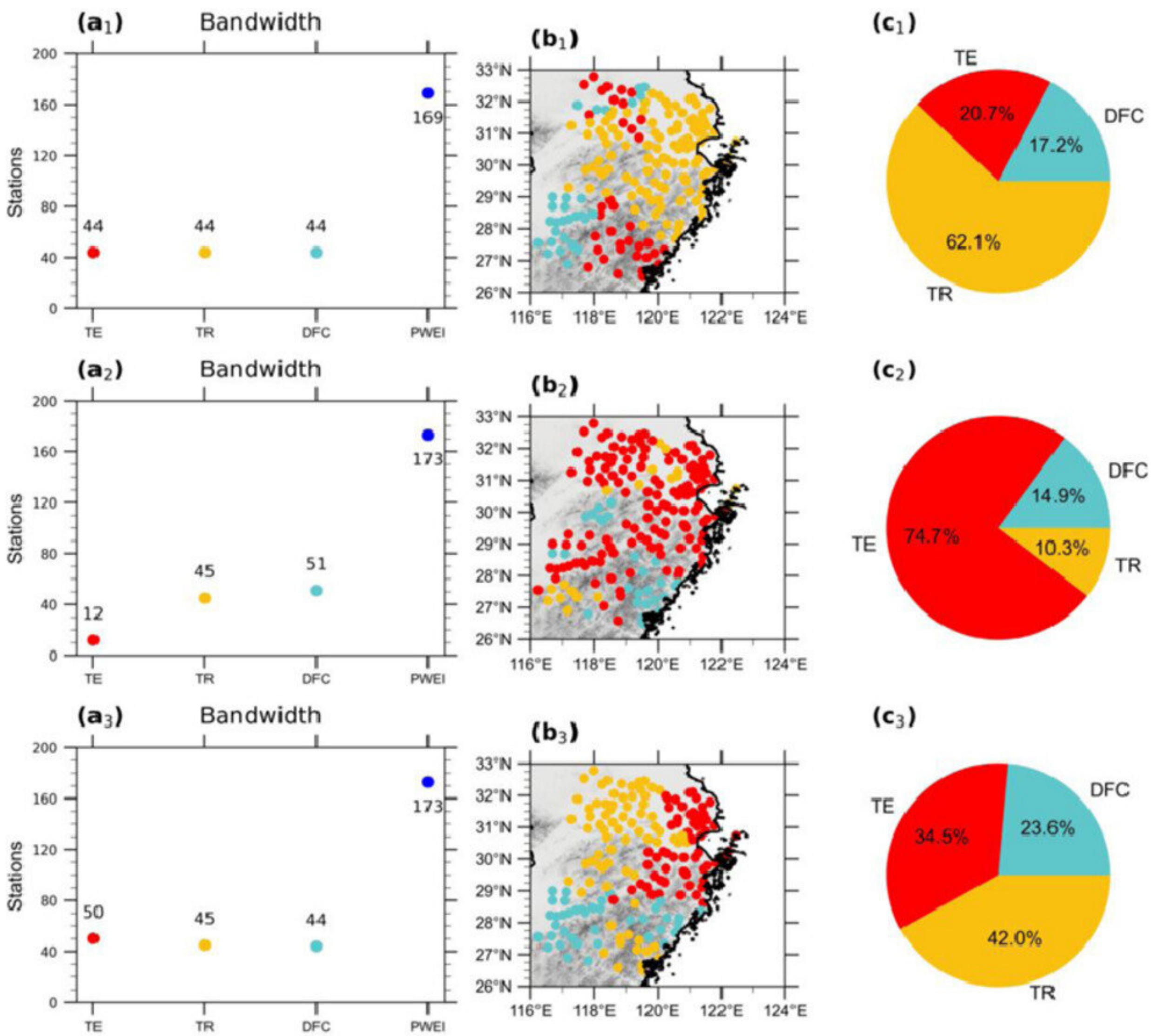

Dominant topographical factors in the precipitation for the observed and simulated precipitation datasets: (1) observation; (2) 28-km simulation; (3) 2-km simulatio; (a1–3) bandwidths for each topographical factor; (b1–3) dominant topographic factors at 174 CMA stations; (c1–3) statistics over the whole study region. Credit: *Atmospheric and Oceanic Science Letters* (2022). DOI: 10.1016/j.aosl.2022.100287

The technique referred to as "dynamical downscaling," which involves the use of regional climate models to dynamically infer the effects of large-scale climate processes at local scales, has proved to be an effective way to simulate precipitation at high resolution. Moreover, with advancements in supercomputing capabilities, dynamical downscaling is now progressing to the kilometer scale.

Previous studies have shown that kilometer-scale dynamical downscaling models (DDMs) capture precipitation characteristics more realistically than DDMs operating at scales of several tens of kilometers. However, our understanding of the mechanism behind the advantages of kilometer-scale simulation remains limited.

Professor Yanhong Gao and her research team from Fudan University, China, have explored a large number of DDMs at quarter-degree resolution (approximately 25–30 km), and took the lead in conducting 4-km grid spacing simulations over the Tibetan Plateau.

Then, more recently, they conducted experiments with two DDMs at the 2-km scale and the traditional quarter-degree resolution in a domain covering the densely populated and economically developed region of eastern China. The relationships between topography and precipitation were established using the method of multi-scale geographically weighted regression (MGWR), and the results were evaluated against weather station observations.

First, they reconfirmed that kilometer-scale DDMs better describe the observed precipitation characteristics than DDMs operating at quarter-degree resolution. Then, delving deeper into the reasons why, it was found that the small-scale topography played a dominant role in the observed precipitation distribution at most weather stations in eastern China, and the kilometer-scale DDM reproduced these observed effects of topography on precipitation more accurately than the quarter-degree DDM. These results have been published in *Atmospheric and Oceanic Science Letters*.

The important influences of topography on the formation and distribution of precipitation have been recognized in many studies. Based on this consensus, Prof. Gao and her team selected five topographical factors commonly used in studies of the relationships between topography and precipitation—namely, topographical elevation, topographical slope, topographical relief, distance from coastline, and prevailing wind direction.

Several regression methods were compared and the MGWR method was found to perform the best in exhibiting the influence of the topographical factors on the spatial distribution of precipitation. This was because of its advantages in reflecting the scale effects of the different factors on the distribution of the precipitation based on the bandwidth; that is, a factor with a smaller bandwidth had a stronger influence on the spatial heterogeneity of precipitation.

According to the weather station observations, the topographical relief, topographical elevation, and distance from the coastline all had small bandwidths and showed important influences on the heterogeneity of the precipitation distribution in eastern China. Among them, the topographical relief was the dominant local factor at about 3/4 of the stations.

"Compared with the quarter-degree DDM, the kilometer-scale simulation had the advantages of a finer horizontal resolution and, furthermore, it was able to more precisely describe the sub-grid topographical features and capture the influences of sub-grid surface variations in precipitation. The discrepancies arising from coarse-resolution modeling of the topography–precipitation relationship might be a cause of mismatched precipitation between observations and simulations," explains Prof. Gao. "This implies a potential way forward for improving the simulation of precipitation."

By expounding the mechanisms underpinning the differences between kilometer-scale and quarter-degree DDM results from the perspective of the relationships between topography and precipitation in eastern China, this research emphasizes the key role played by sub-grid variations in the underlying surface in the simulation of precipitation. This could prove crucial as attempts are made to further improve the simulation performance of numerical weather models.

More information: Li Zeng et al, Evaluating the effects of topographical factors on the precipitation simulated by kilometer-scale versus quarter-degree dynamical downscaling models in eastern China, *Atmospheric and Oceanic Science Letters* (2022). DOI: 10.1016/j.aosl.2022.100287

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