Evaluation of extreme precipitation in the Yangtze River Delta Region of China using a 1.5 km mesh convection-permitting regional climate model

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Abstract

Realistic representation of rainfall characteristics on local scales by state-of-the-art climate models remains a key challenge, especially on sub-daily timescales. In this study, the convection-permitting Weather Research and Forecasting (WRF) model configured with 1.5 km grid spacing is used to simulate precipitation on sub-daily timescales over the Yangtze River Delta Region of China for continuous 10 years (2005–2014). The simulations are compared with rain gauge observations, reanalysis data, and the simulations of a lower resolution WRF with 9 km grid spacing that has a parameterization of convection. The results show that precipitation over the region can be well captured by using the convection-permitting model (CPM). Furthermore, the intensity, duration and coverage of these precipitation events can be more accurately described by the CPM. On the convection timescales of 1–4 hours, especially for heavy rainfall events, the CPM is more accurate than the convection-parameterized model in capturing the short-duration events, which may be due to its better account of physical processes related to the convection on the convection-permitting scale. In addition, the extreme events which are more localized and with short-duration can be represented better by the CPM while the convection-parameterized model tends to produce widespread precipitation events covering more grid cells than observations Biases of the simulation by the 9-km mesh convection-parameterized mode appear to be related to the deficiencies in the representation of convections.

Full Text

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Figures

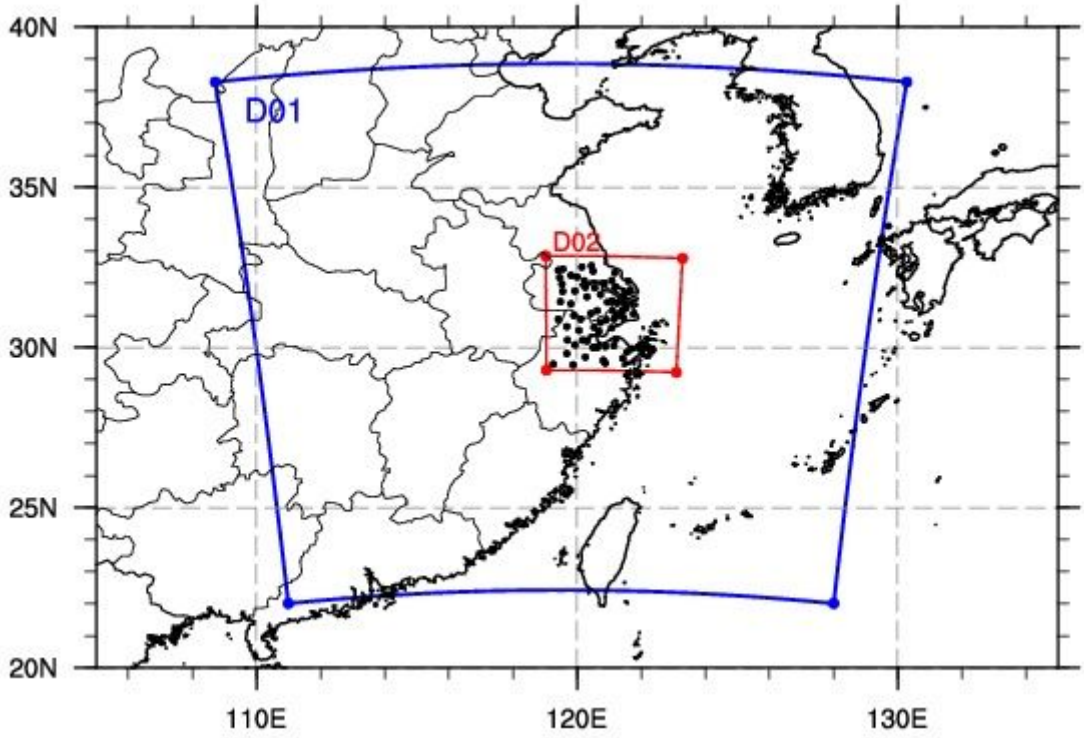

Figure 1

The domains of the WRF model domain configuration in this study: the boundary of the 9-km-resolution outer domain (D01, blue) and the 1.5-km-resolution inner domain (D02, red). Black dots are the locations of automatic weather stations used in the model evaluation. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

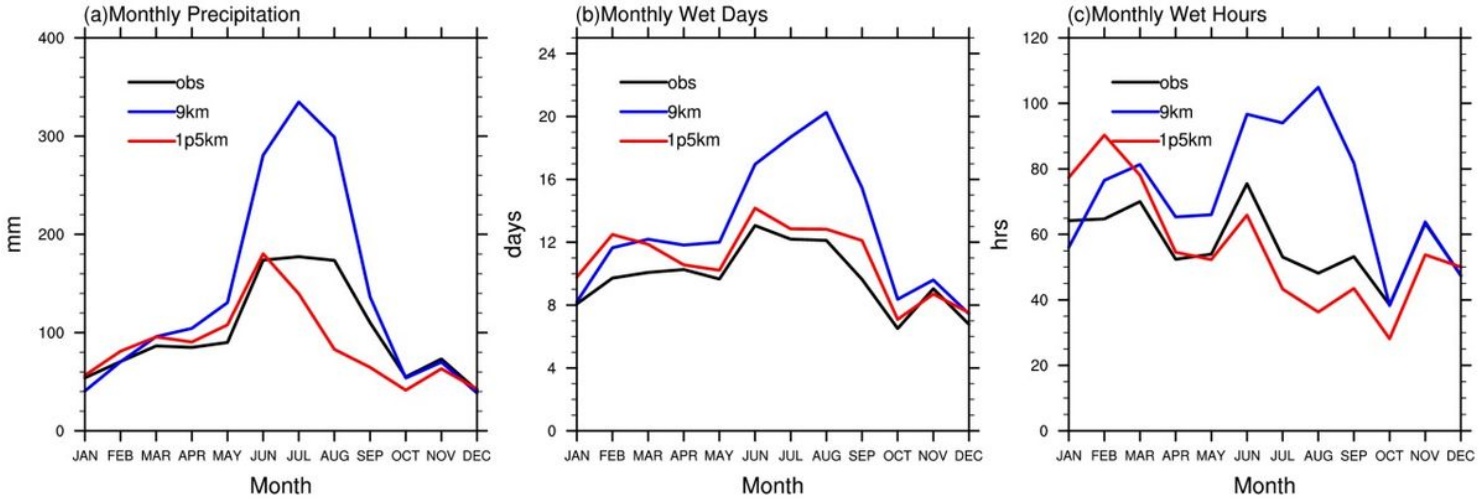

Figure 2

Seasonal cycles of monthly mean (a) precipitation, (b) wet days and (c) wet hours. Wet days/hours are define as precipitation ≥1 mm d−1 or 0.1mmh−1 respectively.

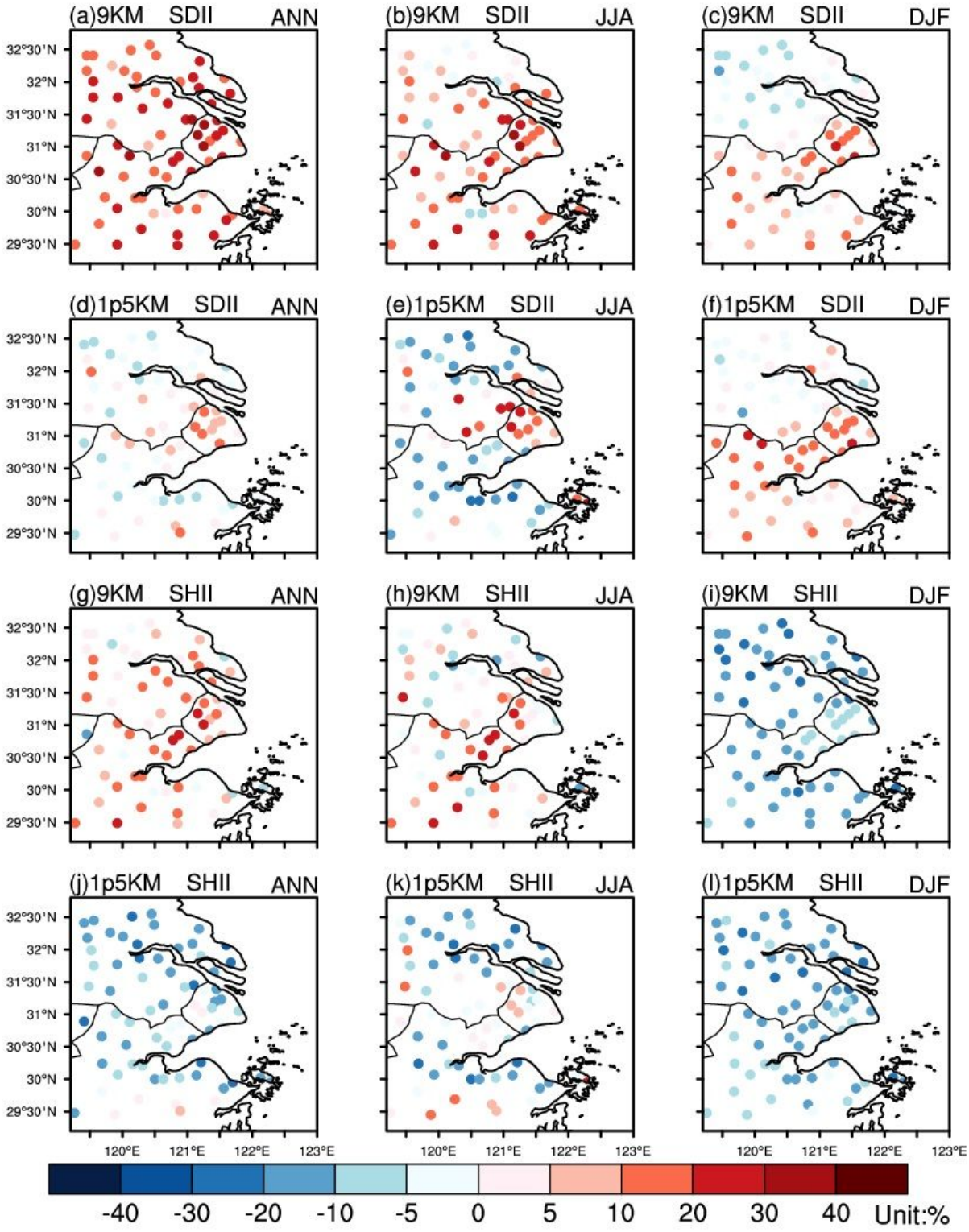

Figure 3

Biases of the RCM-simulated precipitation intensity compared with the observations on (a–f)daily and (g-l) hourly scales. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal

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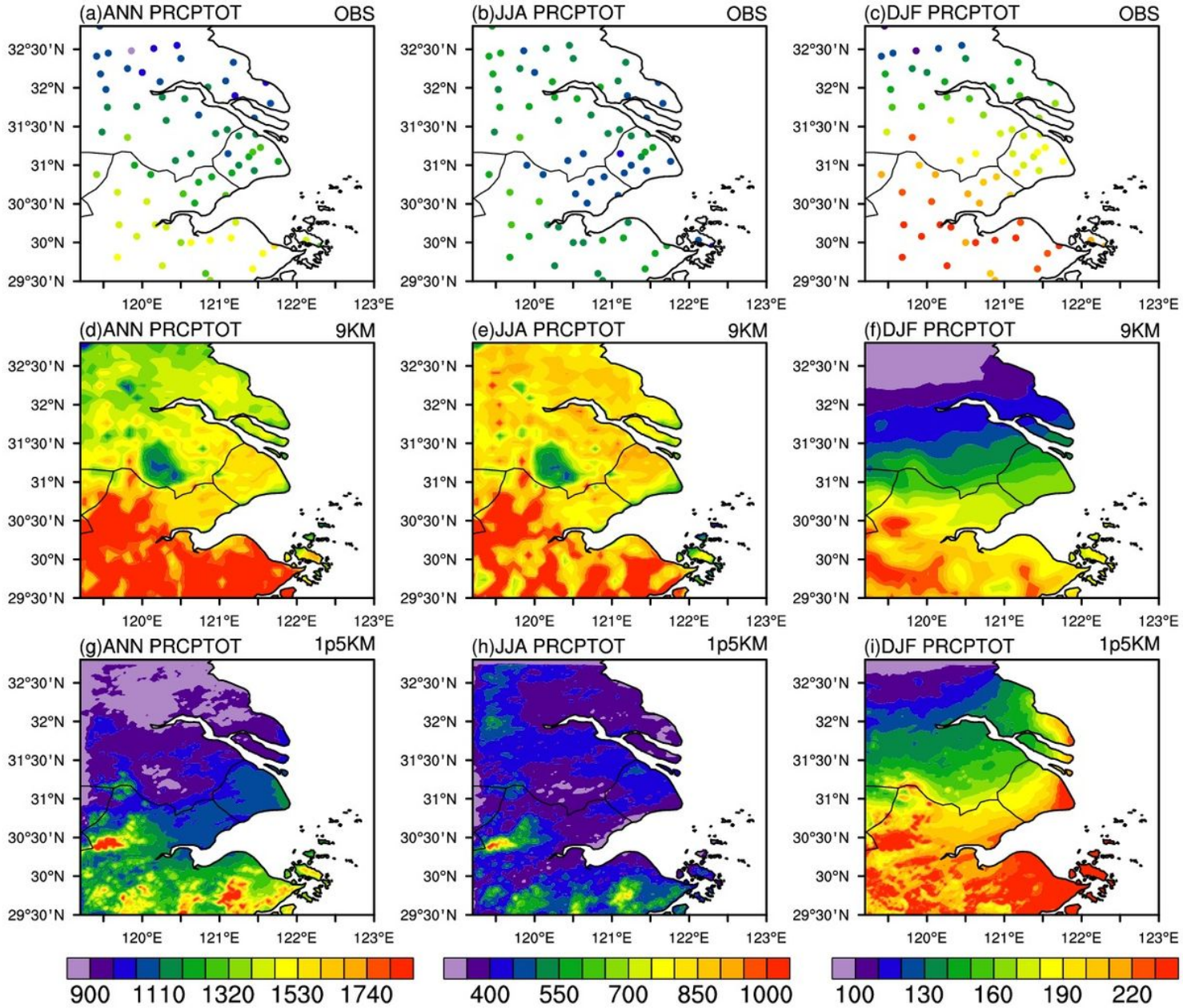

Figure 4

Spatial distribution patterns of annual mean (2005–2014) and seasonal mean precipitation in the observations (top) and the simulations by the RCMs (middle: W9k; bottom: W1p5k) (unit: mm). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

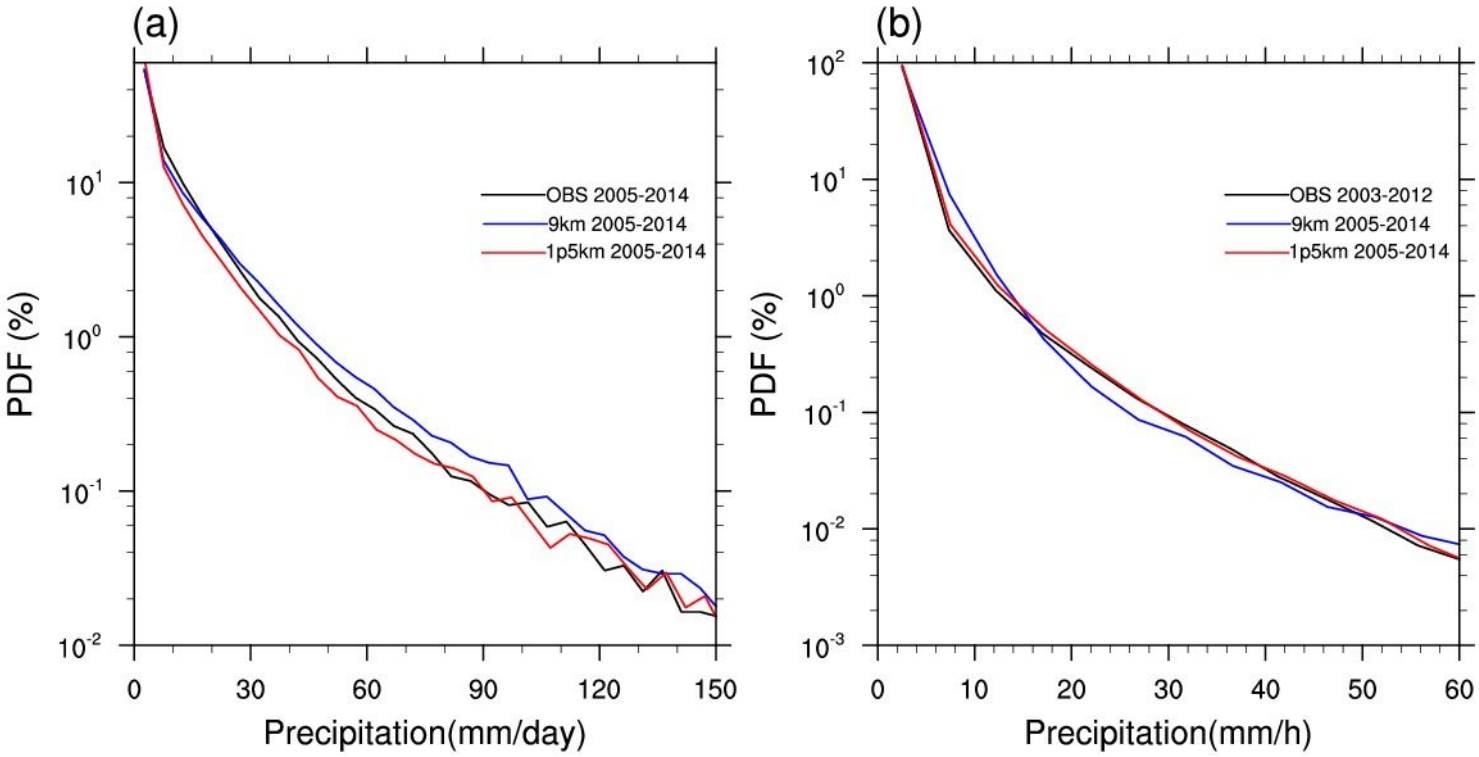

Figure 5

Observed and two RCM simulated frequency distributions of the (a) daily and (b) hourly precipitation intensity

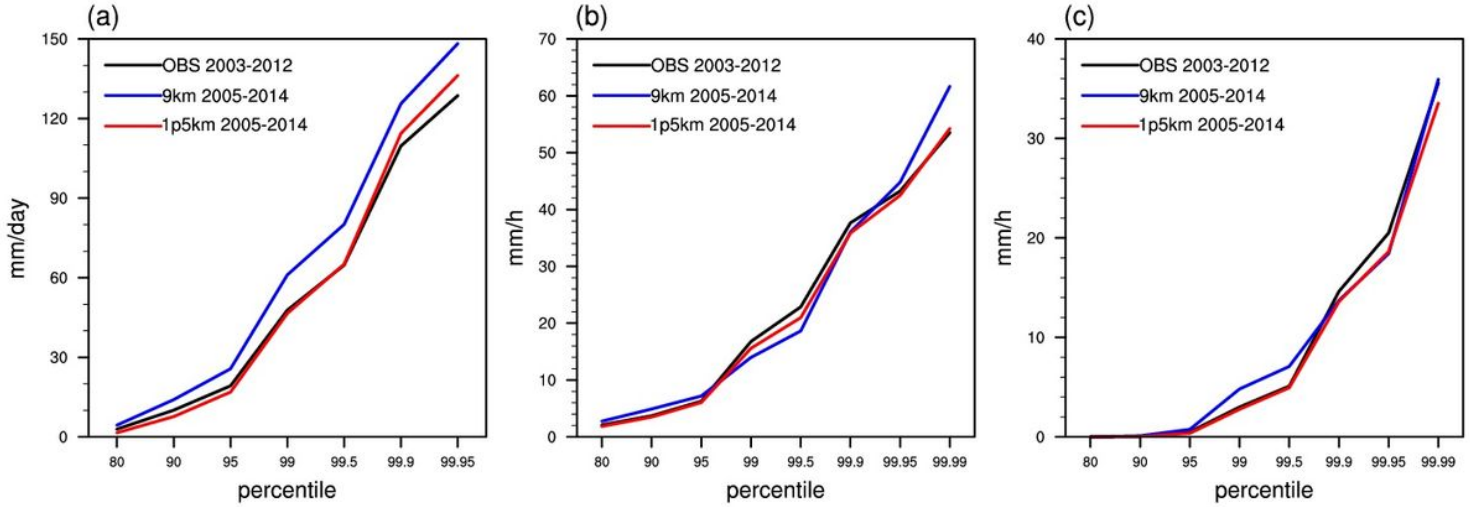

Figure 6

(a) Daily precipitation intensity, (b) hourly intensity for cases with precipitation > 0.1 mm h−1 and (c) hourly intensity in all hours corresponding to a given percentile threshold in the observations and simulations by W1p5k and W9k during 2005–2014. The horizontal axis means the percentile threshold of hourly precipitation across the evaluation period (10 years).

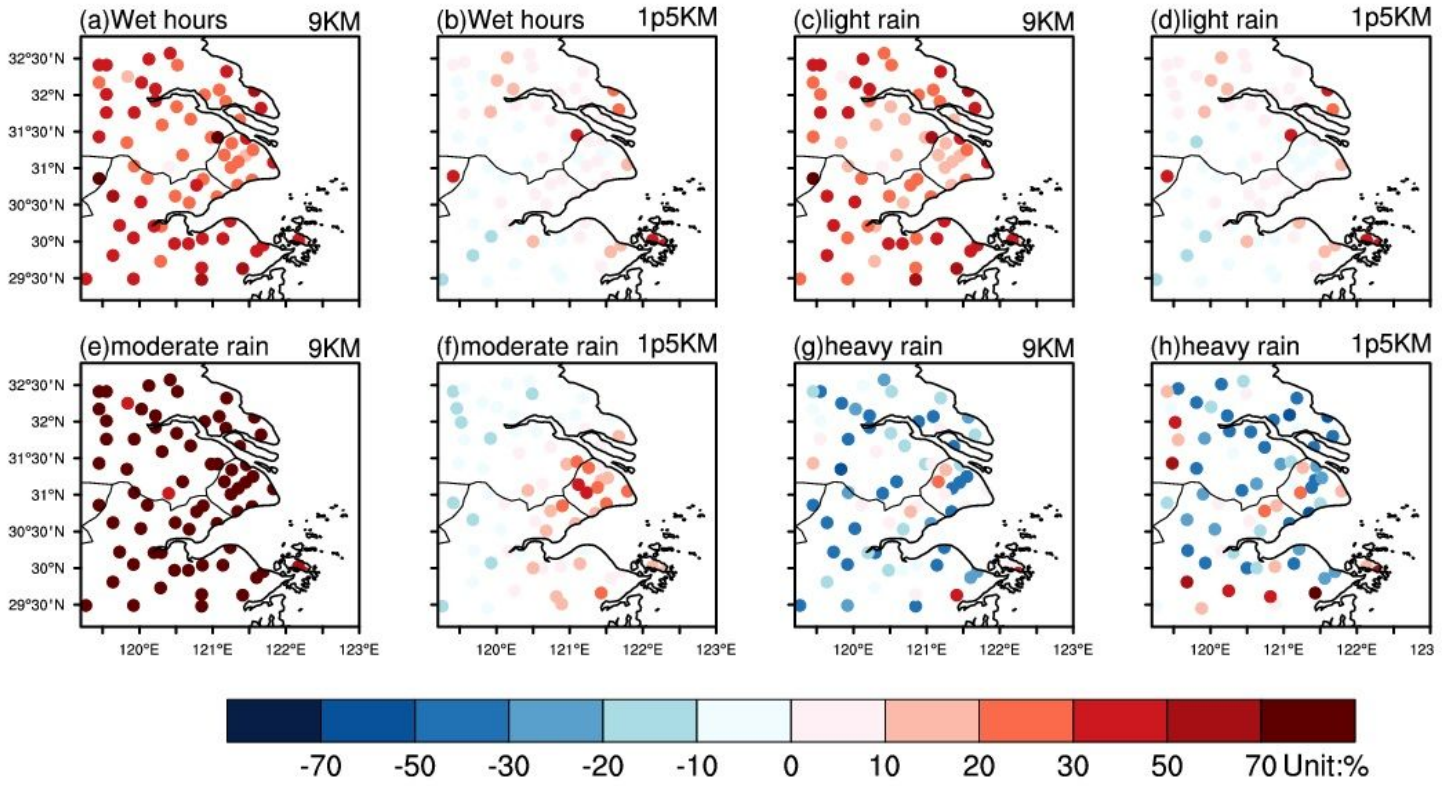

Figure 7

Difference of the RCM-simulated frequencies with the observation at different precipitation grades, which are (a–b) wet (> 0.1 mm h−1), (c–d) light rain (0.1–5.0 mm h−1), (e–f) moderate rain (5.0–20.0 mm h−1) and (g–h) heavy rain (>= 20.0 mm h−1), respectively. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

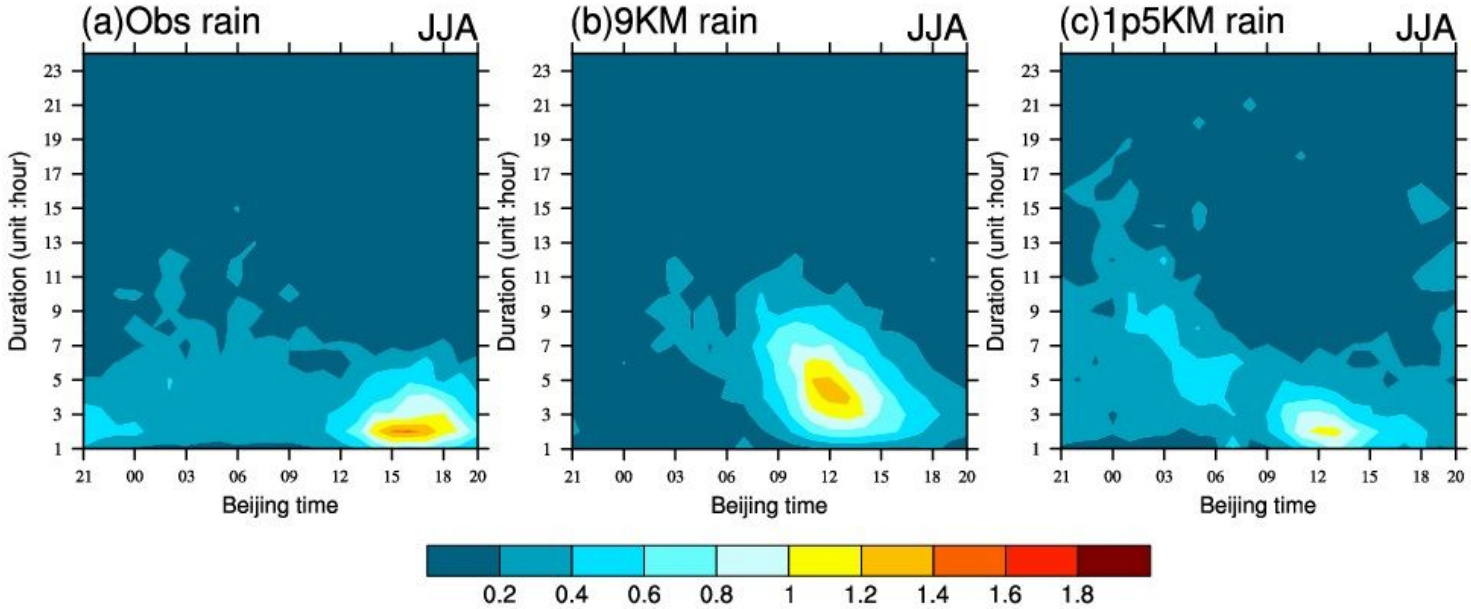

Figure 8

The diurnal cycles of different durations of the intensity of precipitation to its total precipitation for the (a) observation, (b) W9k and (c) W1p5K (unit: %) in JJA. The horizontal axis represents the Beijing time, and the vertical axis indicates the duration of the precipitation events and the shaded colors are the corresponding ratios to total precipitation. Note the events longer than 24 hours are not shown.

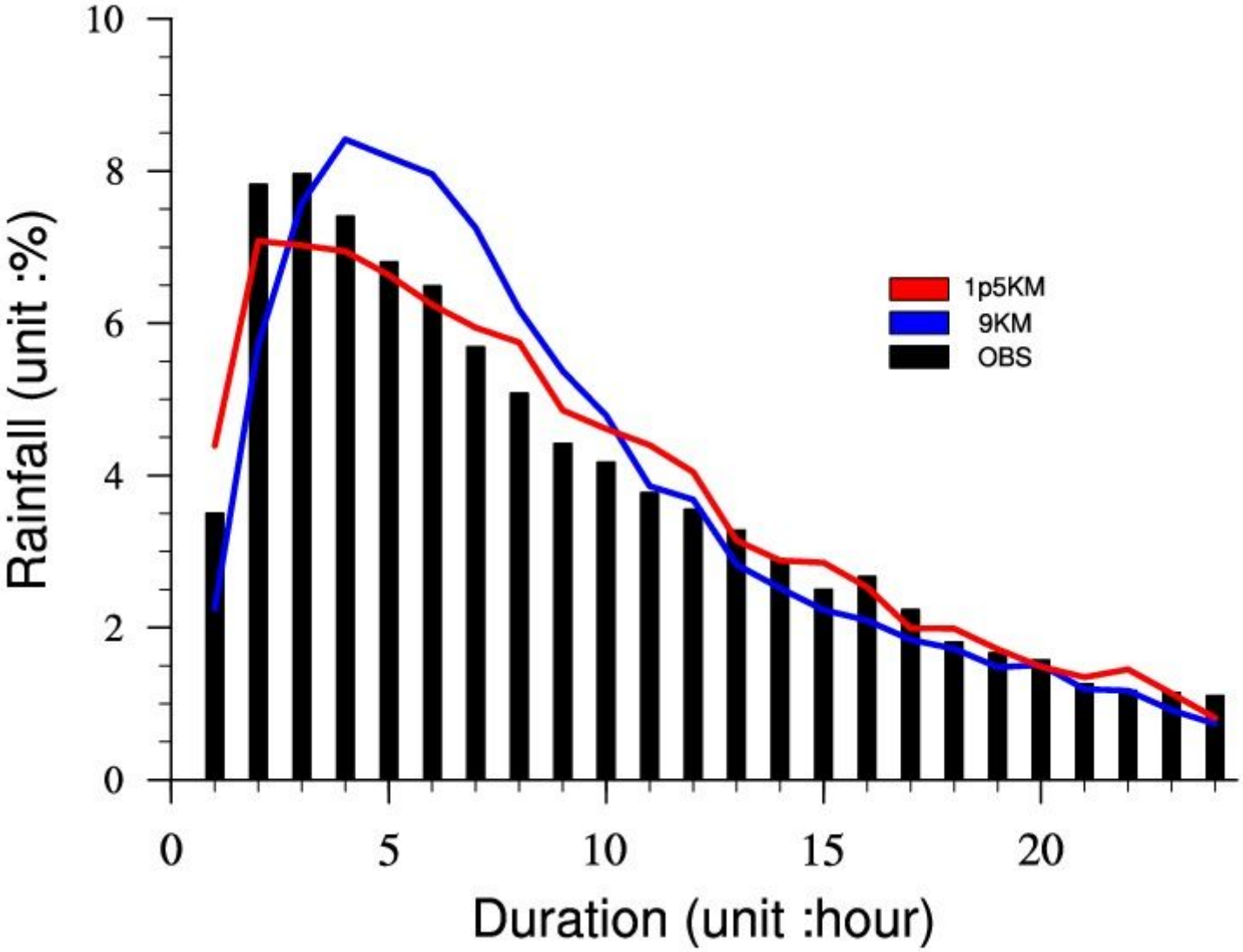

Figure 9

Ratio of the precipitation with different durations to the total precipitation (unit: %, events with durations longer than 24 hours are not shown) in the observation (black bar) and the two simulations by W9k (blue solid line) and W1p5k (red solid line) in JJA. The horizontal axis represents the duration of the precipitation event (> 0.1 mm, unit: hour), and the vertical axis represents the proportion of precipitation with different durations to the total precipitation (unit: %).

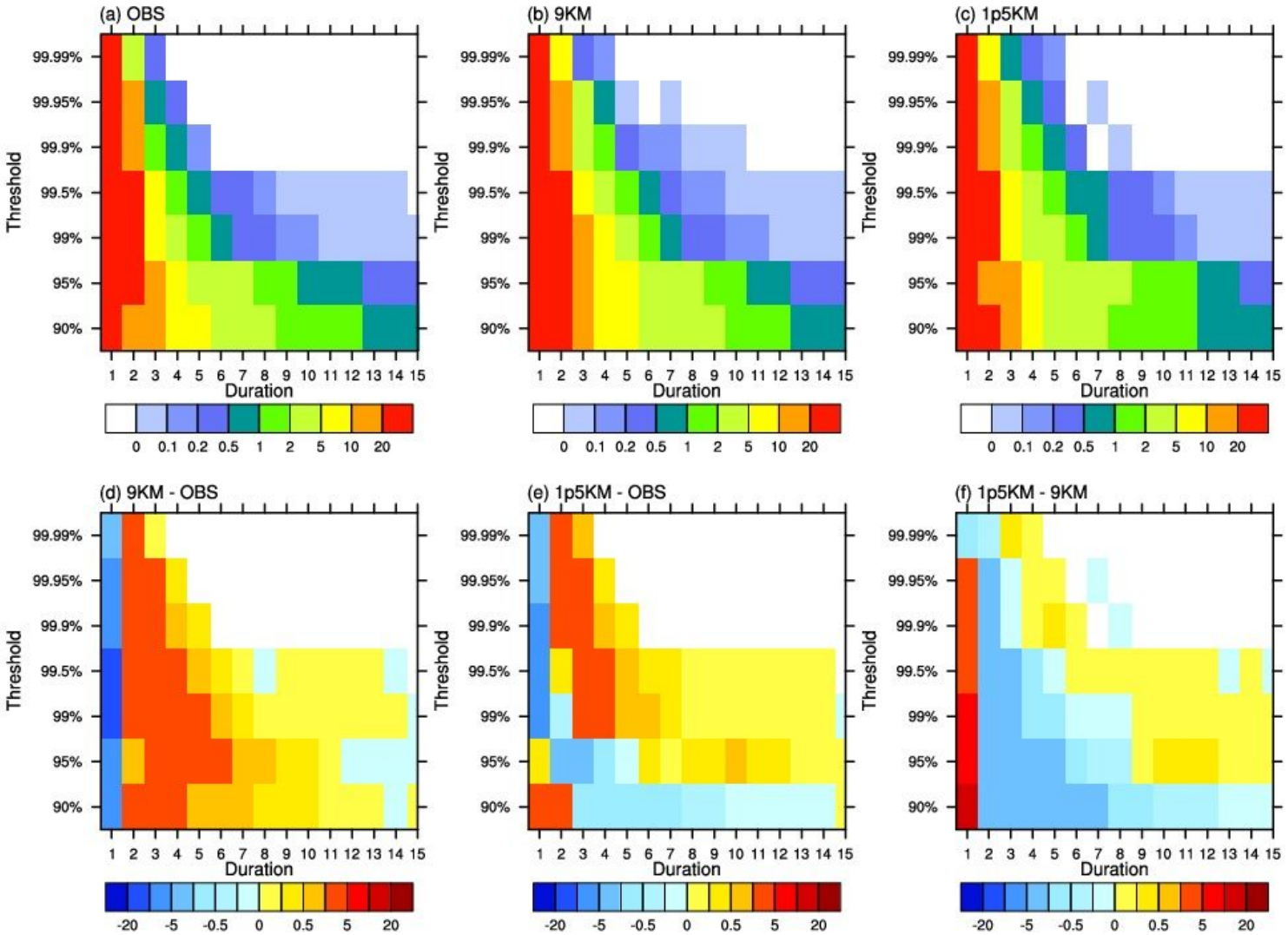

Figure 10

Probability distribution of rainfall duration exceeding intensity percentile thresholds(unit: %) for (a) OBS, (b) W9k, (c) W1p5k, as well as the difference for (d) W9k–OBS, (e) W1p5k–OBS and (f) W1p5k–W9k. The threshold used here is defined in Fig.6c (calculated for all the hours).

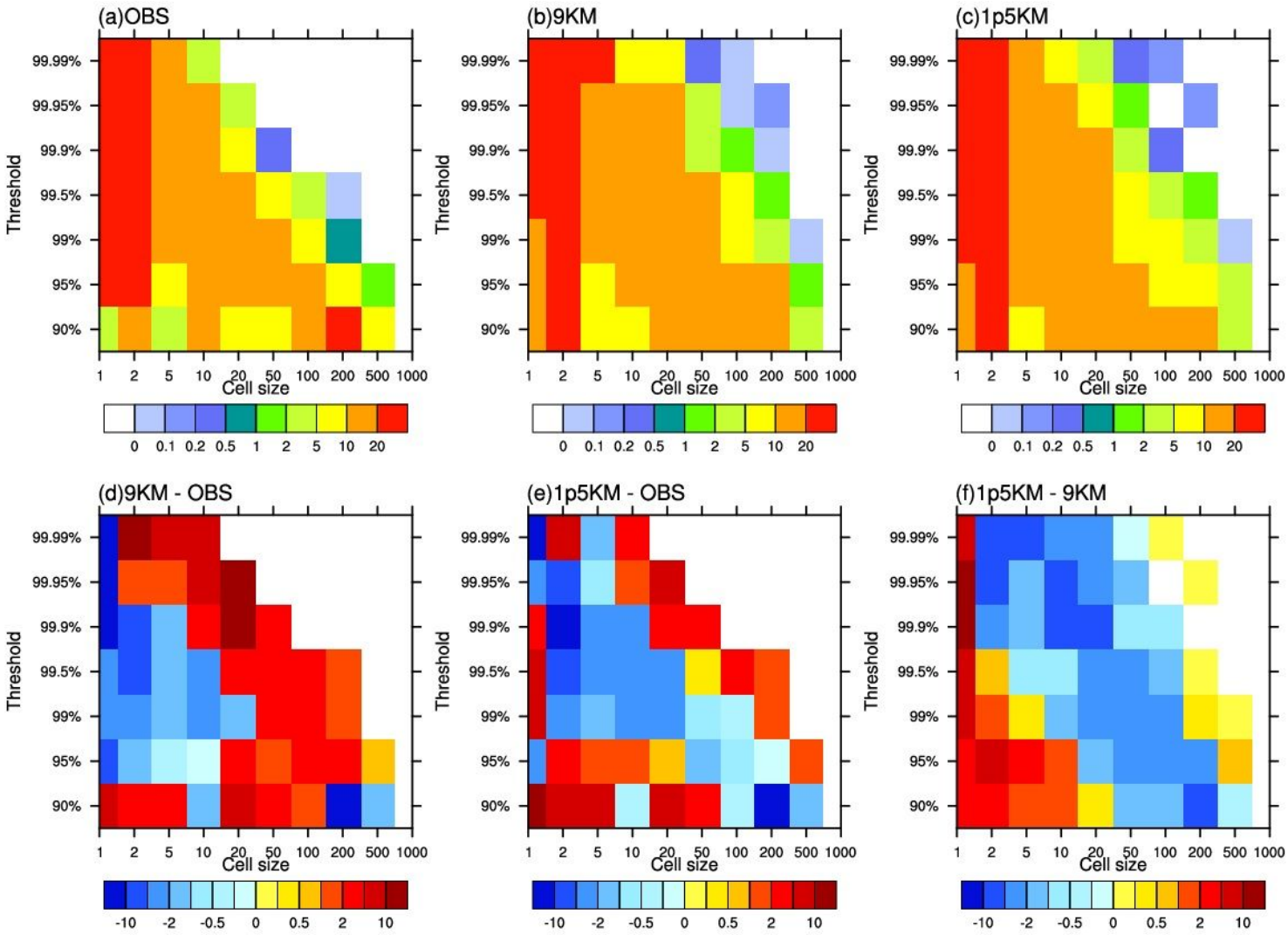

Figure 11

Probability distribution of rain cell size where rainfall over given percentile thresholds (unit: %). The data are interpolated to the grids with the resolution of 10 km×10 km in the same region. Results are shown for (a) OBS, (b) W9k, (c) W1p5k, as well as the difference for (d) W9k–OBS, (e) W1p5k–OBS and (f) W1p5k–W9k. The threshold used here is defined in Fig.6c (calculated for all the hours).

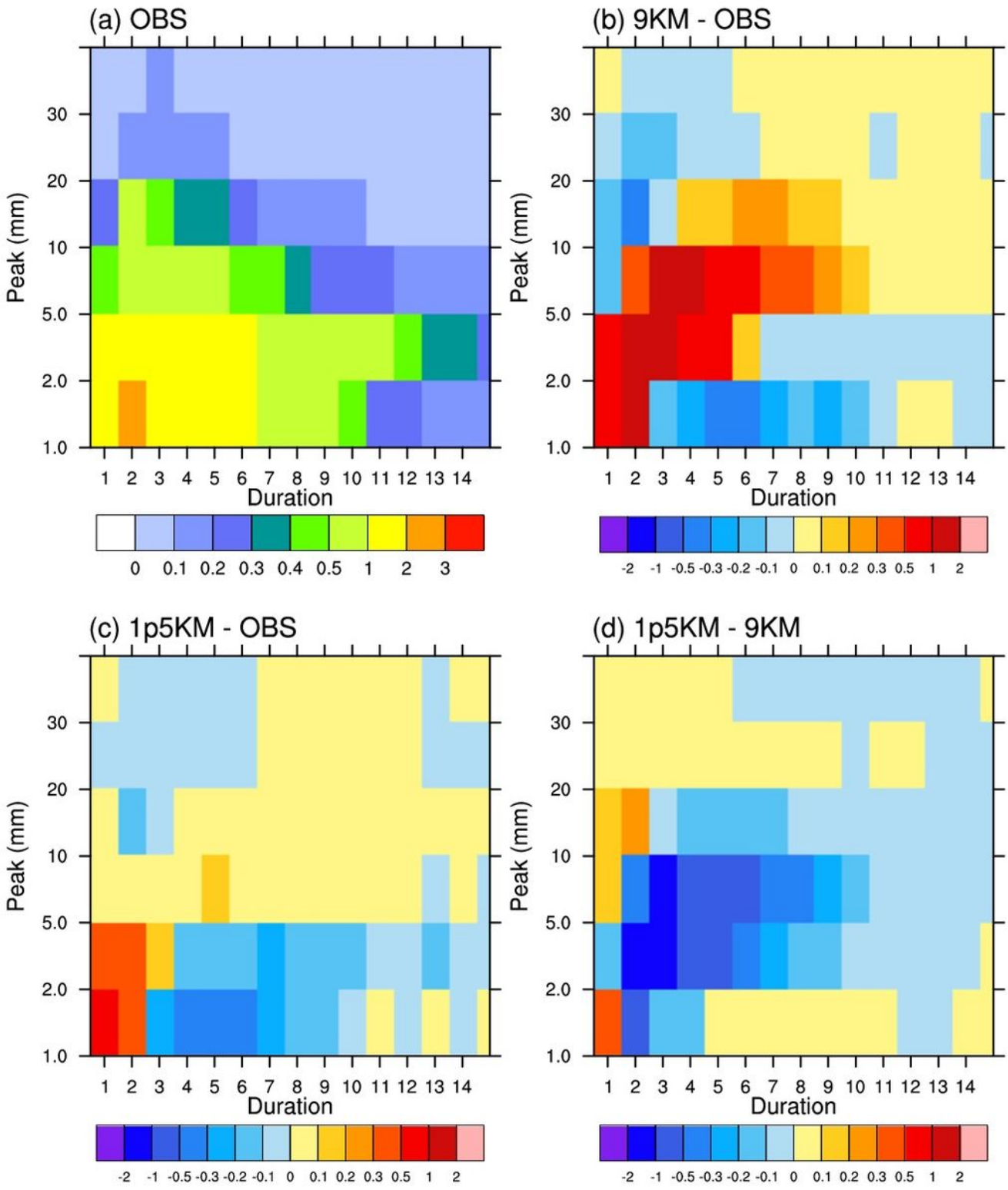

Figure 12

Joint probability distribution of duration versus peak intensity for rainfall ≥ 0.1 mmh−1 (unit: %). Results are shown for (a) OBS, (b) W9k−OBS, (c) W1p5k−OBS and (d) W1p5k−W9k.

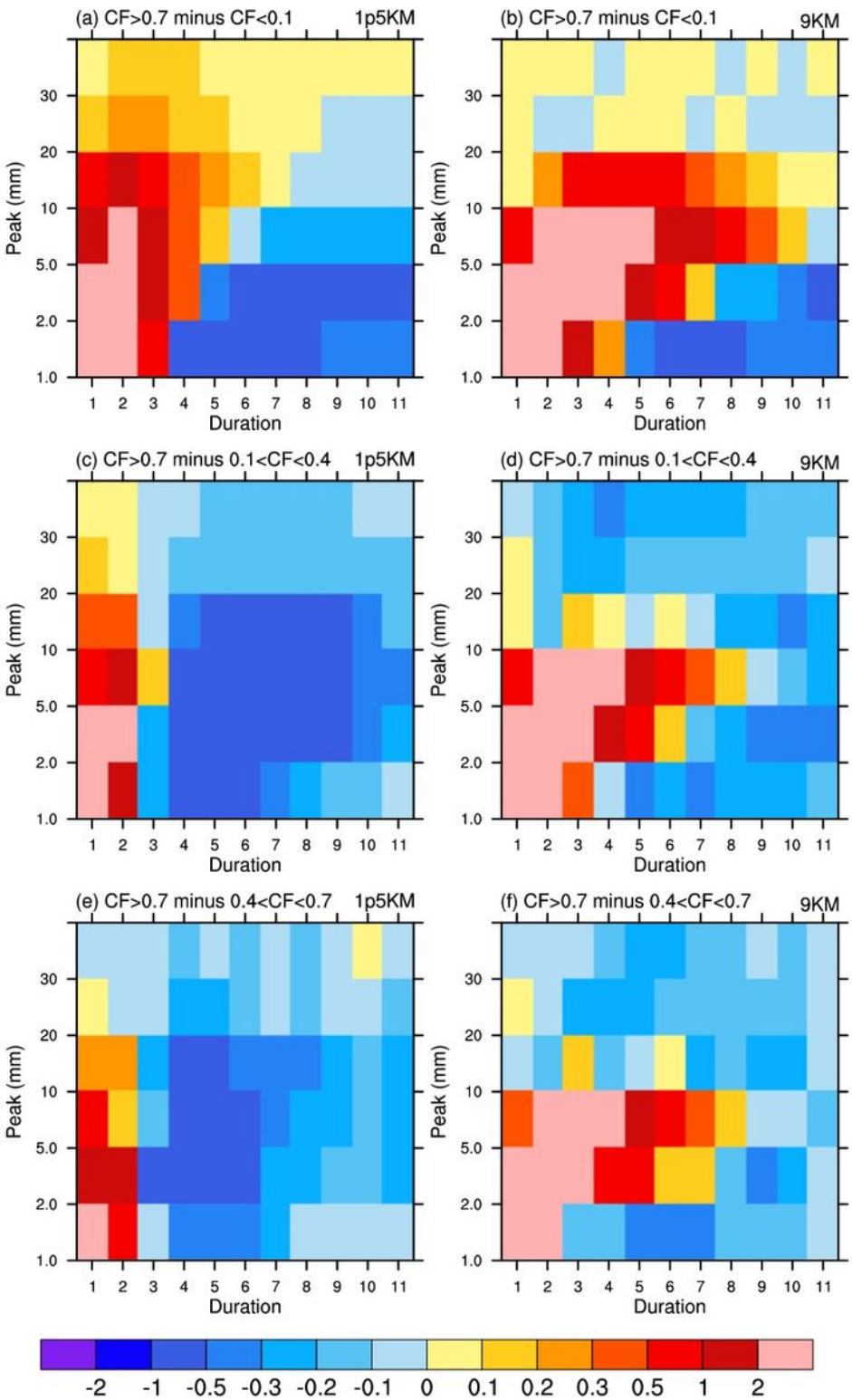

Figure 13

Differences in the joint probability distribution of rain duration versus peak intensity for different CF ranges. Results are high convective fraction (CF ≥ 0.7) days minus lower level convective fraction days.

Supplementary Files

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