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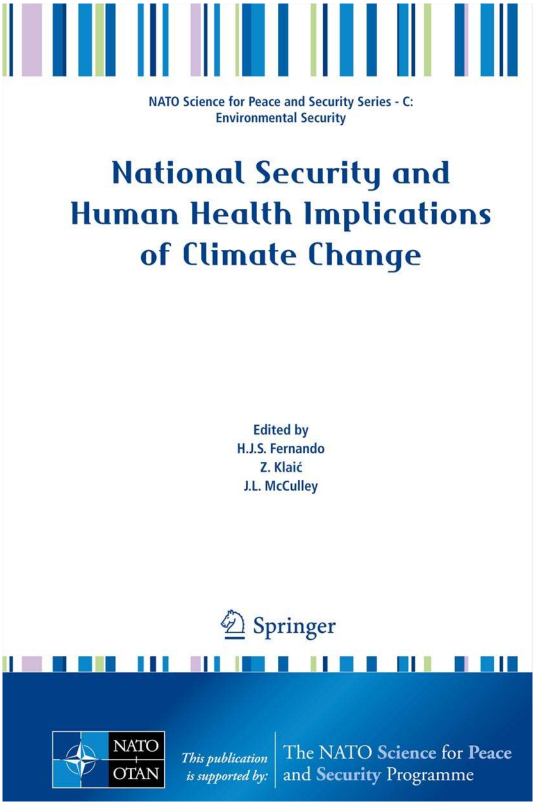

Chapter 26
Orographic Precipitation Simulated by a Super-High Resolution Global Climate Model over the Middle East

Pinhas Alpert, Fengjun Jin, and Haim Shafir

Abstract A super-high resolution (20 km) global climate model data and Climate Research Unit (CRU) data were employed to investigate the seasonal precipitation regime over the Middle East, and the main research focus is on the orographic rainfall effects over a large part of Turkey by using these two different datasets.

Results show that the 20 km regional precipitation over high mountains behaves differently in the 20 km resolution as compared to the CRU data for the time period of 1979–2002. The orographic precipitation over Turkey simulated by the 20 km GCM shows that, the amount of seasonal precipitation has significant relation with the altitude, which is not as pronounced in the CRU data. The area mean precipitation from the 20 km GCM is higher than that of CRU both for the wet and the dry seasons, with the mean value of about 25% and 39% higher, respectively. Results suggest that the higher resolution model is essential, especially in capturing the orographic precipitation over high altitudes.

Keywords Orographic precipitation • Climate model • Mediterranean • Middle East

26.1 Introduction

Orographic precipitation is a central part of the interaction between the land surface and the atmosphere. Not only it is important for natural ecosystems and for the management of human water resources but it also has significant ramifications for other physical components of the Earth system. For example, on short timescales,

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natural hazards such as flash floods, landslides, and avalanches are impacted by precipitation intensity in mountainous regions (e.g., [5–7]). The physical mechanisms involved in orographic precipitation comprise a rich set of interactions encompassing fluid dynamics, thermodynamics, and micro-scale cloud processes, as well as being dependent on the larger-scale patterns of the atmospheric general circulation [4, 12]. During the past, many studies on this subject over different mountain areas, have been published. A comprehensive discussion on this subject can be found at Roe, [12]. Alpert et al. [2] provide a review on the prediction of meso-gamma scale orographic precipitation.

The orographic effect on the rainfall over the Middle East (ME) has been investigated during the past [3, 4]. This note focuses on the significant difference between the fine and the coarse resolution in climate runs in the accurate simulation of the orographic precipitation over the ME with implications to all high mountains rainfall.

26.2 Data

A super-high resolution 20 km grid GCM data developed at the Meteorological Research Institute (MRI) of the Japan Meteorological Agency (JMA), was used here. It is a climate-model version of the operational numerical weather prediction model used in the JMA. The simulations were performed at a triangular truncation 959 with a linear Gaussian grid (TL959) in the horizontal. The transform grid uses $1{,}920 \times 960$ grid cells, corresponding to a grid size of about 20 km. The model has 60 layers in the vertical with the model top at 0.1 hPa. A detailed description of the model is given in Mizuta et al. [11]. The two runs of the 20 km GCM cover the time periods 1979–2007 for current/control and 2075–2099 for the future. Due to the research focus, only the control run of the 20 km GCM was employed here. In addition, the global time series dataset based on rain gauge measurements (land only) from the climate research unit (CRU, in brevity; Mitchell and Jones, [10]) was employed here for comparison. The CRU grid horizontal resolution is 0.5×0.5 degree, and the time period available is 1901–2002. In order to make these two sets of data to be comparable, the 1979–2002 time periods for both data sets was selected. The study area covers a central high-mountain part of Turkey; four different sizes of domains were selected, for which the largest domain is about 80,000 km^2 (Fig. 26.2a).

26.3 Results and Discussion

26.3.1 The Whole Mediterranean

Figure 26.1 shows that the wet season mean precipitation from the 20 km GCM is quite consistent with the observations based CRU data. Over the Mediterranean (Med in brief) region, the latitudinal gradient is the predominant feature, with a

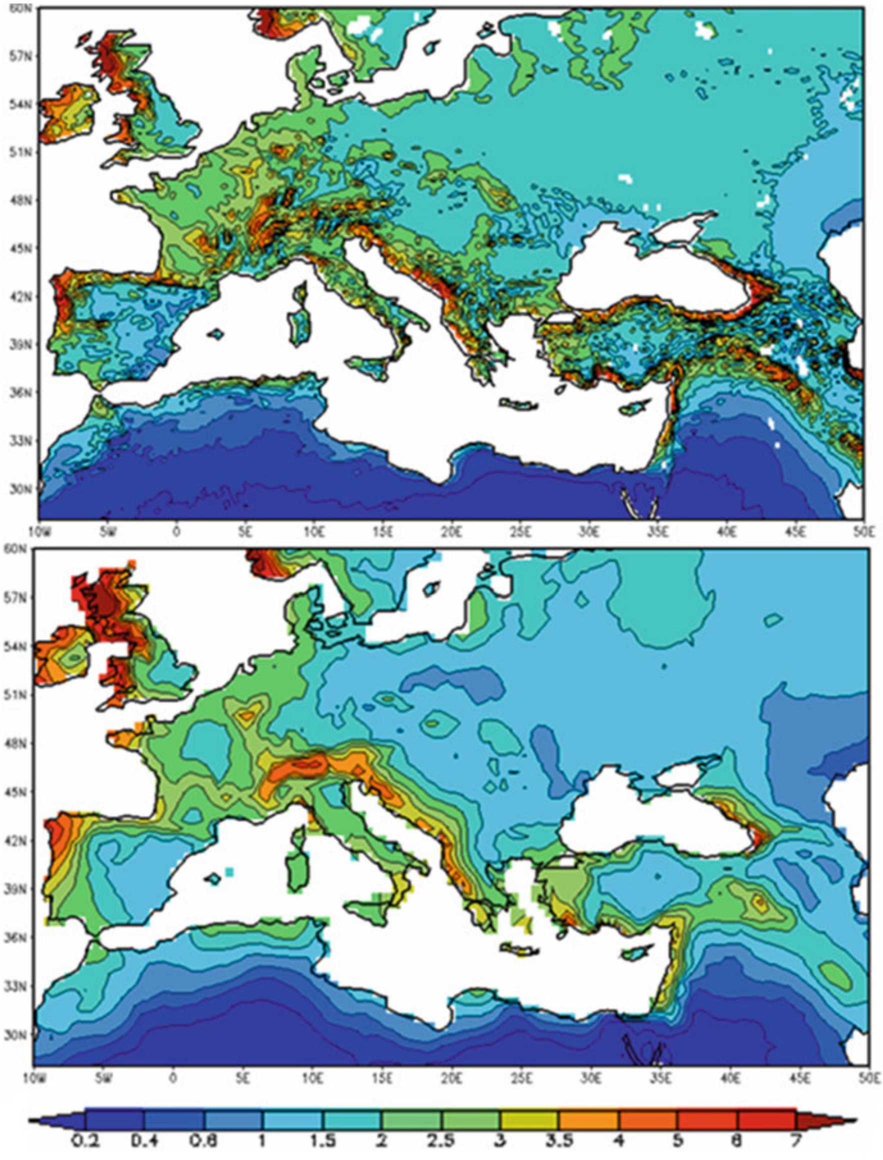

Fig. 26.1 Mean wet season (October–March) precipitation (1979–2002) from the 20 km GCM (*upper*) and CRU (*bottom*). Unit: mm/day

much drier area located at the south of the Med coastline, and a wetter area over the northern coastline of the Med basin. However, a closer examination shows that the amount of the precipitation peaks simulated by the 20 km model are larger than that from the CRU. For instance, this can be well noticed over the Fertile Crescent,

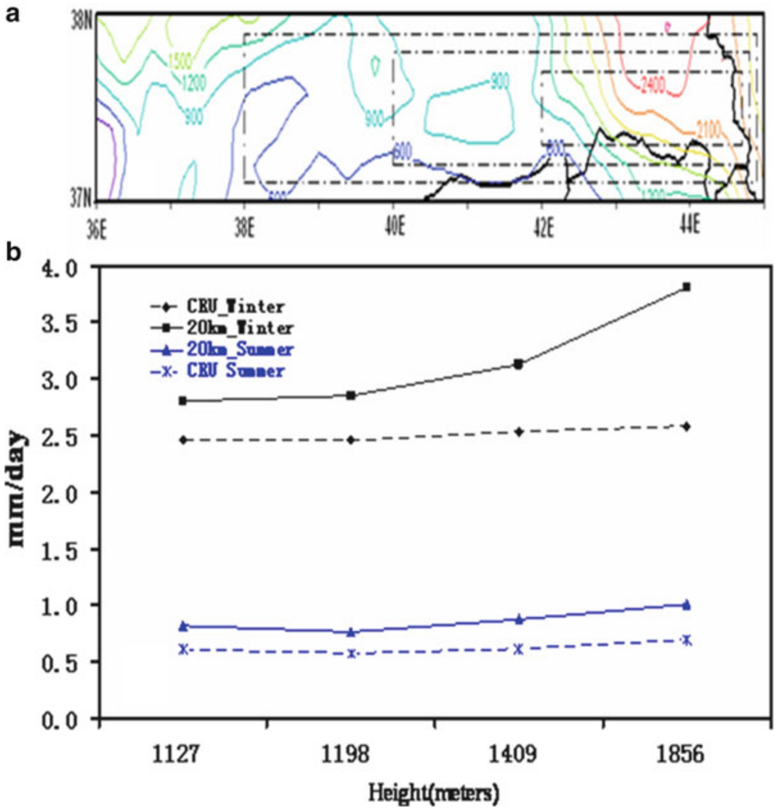

Fig. 26.2 (**a**) The altitude map for the selected four domains over Turkey. Unit: meters. (**b**) Area mean precipitation changes with the mean altitude for the selected four domains both for wet season (October–March; denoted winter in the figure) and dry season (May–September; denoted summer in the figure) for the 20 km control run as well as CRU (1979–2002). Unit: mm/day. The average altitudes of the four domains vary from 1,127 to 1,198, 1,409 and 1,856 m as indicated by the X-axis

the south coast line of Black Sea and over the Alpine mountain region. However, Kitoh et al., [9] showed that the simulated precipitation from 20 km GCM is surprisingly close to that based on the daily raingauge data over the ME [13].

26.3.2 High-Altitudes Orographic Precipitation over Turkey

Figure 26.2 shows the differences between the 20 km GCM and the CRU data in simulating the orographic rainfall, both for the wet season (October–April) and dry season (May–September), over the high mountainous section of Turkey. Figure 26.2b indicates that, over the same domain, the area mean precipitation from the 20 km

GCM is higher than that of CRU both for the wet and the dry seasons, with the mean value higher by about 25% and 39%, respectively. Of-course, in absolute values the differences are much larger in the wet season.

Especially for the highest altitude domain of 1,856 m average altitude, these differences reach the largest values of about 48% and 46% for the wet and dry seasons. Notice that the absolute average differences are of about 1.3 and 0.25 mm/day over that inner domain which is as large as 3 × 0.5 deg (an approximate area of 15,000 km^2).

One major result is that the wet season area mean precipitation is increasing with the altitude as can be clearly seen in the 20 km GCM, but it is not as significant in the CRU data. Also, Jin et al. [8] showed that the outstanding performance of 20 km GCM in simulating the precipitation through the E. Med south-to-north cross-section, suggesting that the high resolution model indeed has an essential role in capturing the orographic rainfall effect.

26.4 Summary

The super-high resolution 20 km GCM data shows its capability in capturing the seasonal precipitation over the Middle East region quite well. The seasonal precipitation simulated by the 20 km GCM is also quite close to that of CRU. However, the effect of orographic precipitation over the high-mountainous region of Turkey with the 20 km GCM shows that, the amount of seasonal precipitation has significant relation with the altitude, which is not as pronounced in the CRU data based on observations. One probable reason for that may be the severe lack in rainfall observations over high mountains as discussed by e.g. Alpert [1]. Due to the orographic effect, the area mean precipitation from the 20 km GCM is higher than that of CRU both for the wet and the dry seasons, with the mean value of about 25% and 39% higher, respectively. Results suggest that the higher resolution model is essential, especially in capturing the orographic precipitation.

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