University of Tabriz

The Role of topography on the occurrence of Springtime Precipitation in the Northwest of Iran: (Case study: Spring 2004)

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Introduction

Springtime Precipitation in Northwest of Iran (NWI) is one of the evidence that reveals important role of Mountains in regional and local scales. Due to the location of NWI in mid-latitude, it can be said, the occurrence of precipitation in NWI is the result of the interaction of multiple scales forcings, including regional (topography, orography and local mechanism) and synoptic scale (Trough, fronts, cyclones). In recent years, applying the regional climate models has been an important role in detecting aspects the mechanism of rainfall occurring in different parts of the world. So that, detecting regional forcings is possible only by using regional models (Giorgi, 1990). These models as an efficient tool, makes the dynamical processes dominant understanding easier on the occurrence of atmospheric and climatic phenomena. Regional topography in the formation of the characteristics of the phenomena of climate plays an important role. So that they can simultaneously act as a mechanical and thermal forcing effect on the climate of the environment around them. In this study, the role of topography on the occurrence of springtime precipitation in the NWI was analyzed.

Materials & Methods

In this research, Regional Climate Model (RegCM4) developed by the ICTP, was used to evaluate the meso-scale effect, interactions and the complex physical-dynamic processes in the occurrence of spring precipitations in the NWI Mountains. A summary of the model configuration that was used in this study are shown in Table 1. Two simulations are carried out for January - June 2004. In the control experiment topography data from GLCC was used. To examine the role of the NWI Mountains in the formation and effect on the local heating, solarize of slopes and forcing orography, an experiment was conducted by removing the NWI topography (Fig. 1b). Results from March to June 2004 are discussed in the present study. Therefore, the model was run twice, once as a control and once as an experimental variation. In the experimental run, the NWI Mountains were omitted from the topographic data (Fig. 1b).

Domain	• MEADLE EAST framework • 20.0, km horizontal resolution • Central Lat. and Lon. 35.00 °N, 45.00°E • 160 (Lat.) ×192 (Lon.)	Cumulus parameterization scheme	• Simplified Kuo (Anthes et al. 1987)
		Planetary boundary layer scheme	Holtslag (Holtslag et al., 1990)
Map projection	Lambert conformal	Land surface model	BATS (Dickinson et al. 1993)
Simulation period	2004010100 -2004063000 (6month)	Vertical layers	23 sigma
Sea Surface Temperature	OI_WK	Resolved scale precipitation	SUBEX (Pal et al. 2000)
Boundary data	ERA-Interim (EIN15)	Radiative transfer	Modified CCM3 (Kiehl et al. 1996)

Table 1. Model Configuration Used in This Study

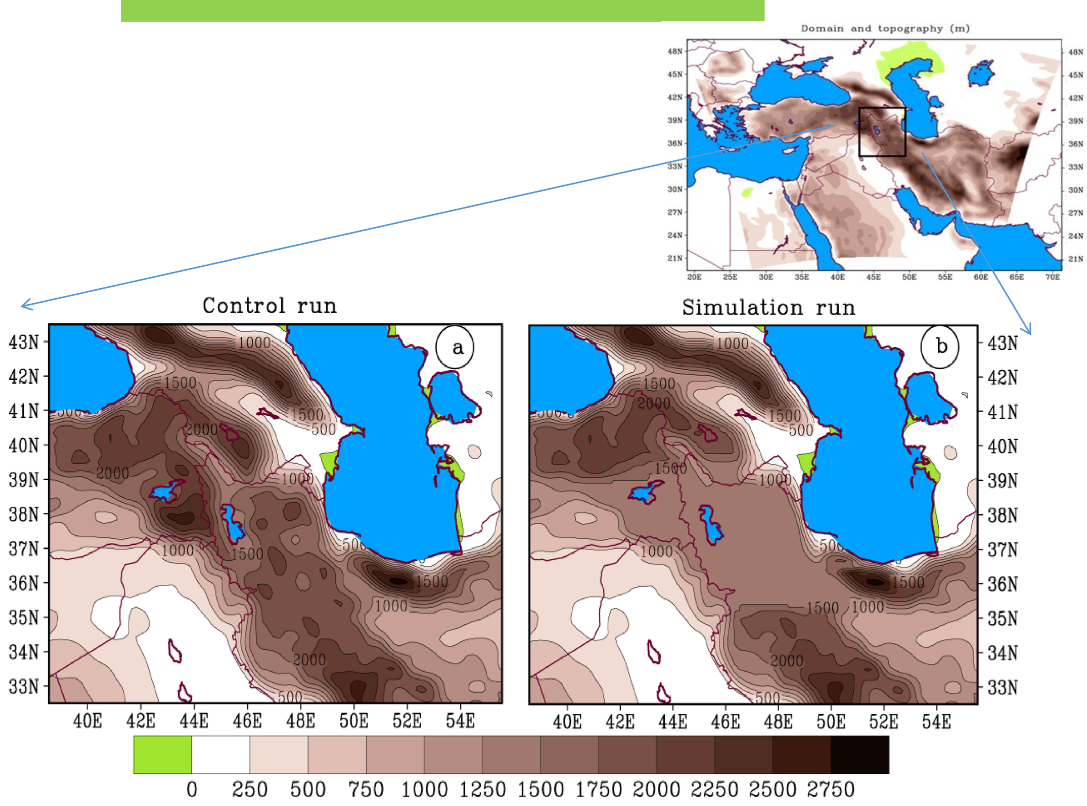

Fig. 1. Domain and topography in the RegCM model. (a) control run, (b) experiment run (units: m).

First, the comparison and evident of observed and modeled spring precipitation in the control and simulation runs was done and the areas with positive and negative difference was identified and analyzed. Then, for understanding dynamical and thermo-dynamical effects and the thermal forcing of the NWI Mountains, in occurrence of spring precipitation, the diabatic heating was exerted as a residual of thermodynamic equation(1). In order to understanding of conditional thermodynamic dominant on upward and downward air motions the diabatic heating was analyzed. The diabatic heating is a useful instrument to examine the sink and source of energy in regional scale. The diabatic heating can observe the specific role of local heating, vertical and horizontal advection of heating, and the total heating in one level or system. In other words diabatic heating equation includes the following three above terms.

$$Q = c_p \left(\frac{p}{p_0}\right)^k \left(\frac{\partial \theta}{\partial t} + \vec{V}.\nabla \theta - \omega \frac{\partial \theta}{\partial p}\right) \qquad (1)$$

Where θ is the potential temperature, V is the horizontal velocity, ω is the vertical *p*-velocity, and *p* is the pressure. In the equation, $k = R/C_P$ where R, and C_P are, respectively, the gas constant and the specific heat at constant pressure of dry air, P_O=1,000 hPa and ∇ is the isobaric gradient operator. The local temporal derivative ($\frac{\partial\theta}{\partial t}$) horizontal advection ($V.\nabla\theta$) and vertical advection ($-\omega \frac{\partial\theta}{\partial p}$) were compared in the control and experimental runs to investigate the role of the NWI Mountains as the heat source of the area. (Rodwell and Hoskins, 2002: Zhang and Wu, 2002: Zarin et al, 2011).

Results

Observed from TRMM data and modeled spring precipitation (March to June 2004) in control and experimental runs has been indicated in Fig. 2. It can be said, the general pattern of precipitation distribution in the region is similar in control and simulation run, and only the maximum rainfall reception zones are difference. In both experiments maximum precipitation was occurrence on the NWI Mountains, Southern Caucasus heights and Ararat Mountains. But, the model estimated with better details and more precipitation relative to observational data.

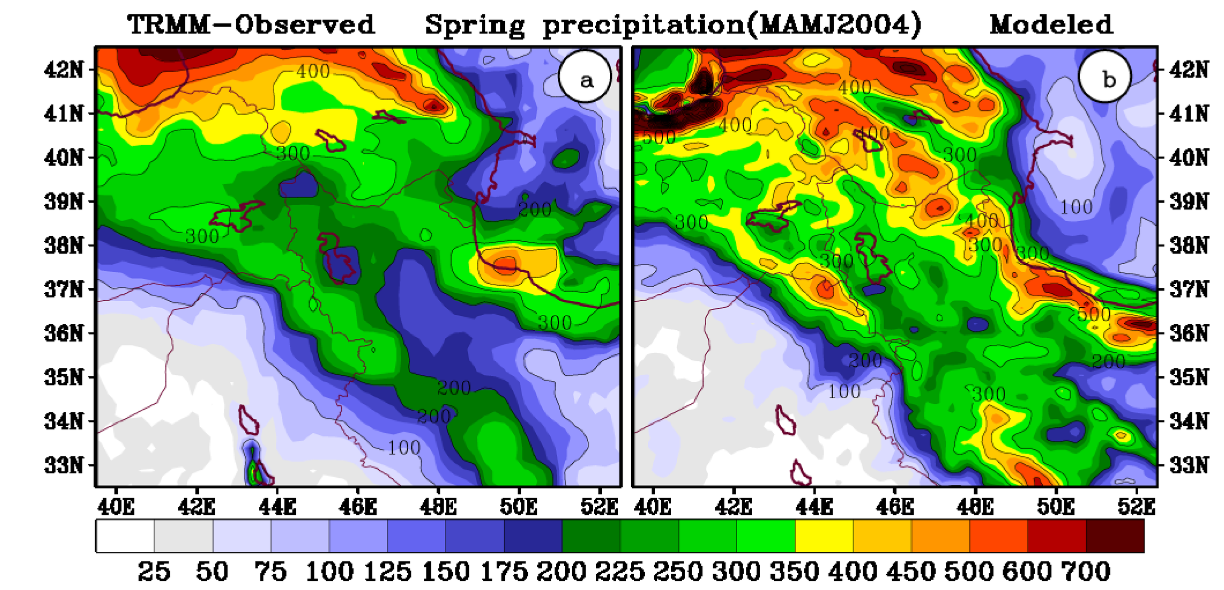

Fig. 2. Observed (a) and modeled (a) spring precipitation from March 2004 to June 2004(mm).

Fig. 3 shows that, there is a negative difference in precipitation up to -250 mm in large part of the NWI. In fact, in terms of smoothing the topography the precipitation in the NWI significantly has decreased. The positive difference cores are outside of the internal NWI on the Alborz Mountains, the Caspian Sea and some amount is consistent with the South Caucasus Mountain. This implies that in terms of smoothing the topography, precipitation in the interior of NWI shifted to the east of the study area matches the above heights.

Fig. 3. Difference between Control and Simulation run for spring precipitation (mm).

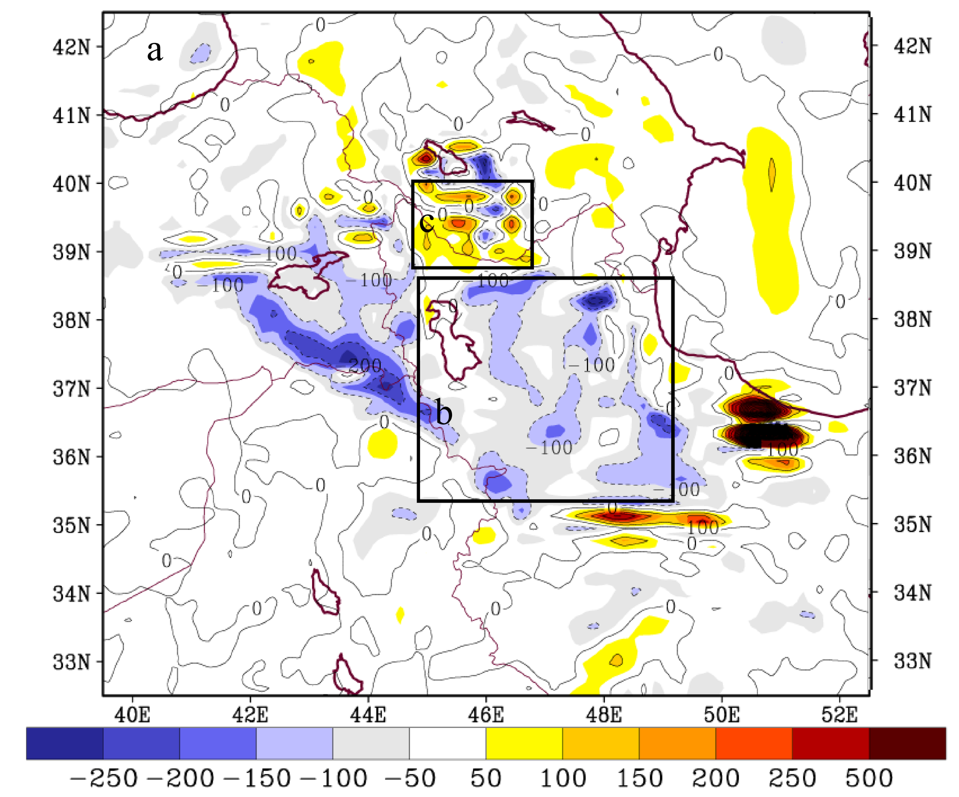

Fig. 4 shows that the area−averaged precipitation time series for control and experiment run, for three domains that showed over Fig. 3. These figures indicate that although the magnitude of precipitation in the internal zone of the NWI was decreased in terms of smoothing the topography, but in general the amount of precipitation occurring in the larger region (a domain) is the same. Actually, precipitation decreased in the internal zones of NWI where its topography is smoothed and it shifts to the border of it, where the topography has not changed. So occurrence more precipitation in the border areas, compensate shortage of precipitation in the inner regions of the larger domain significantly.

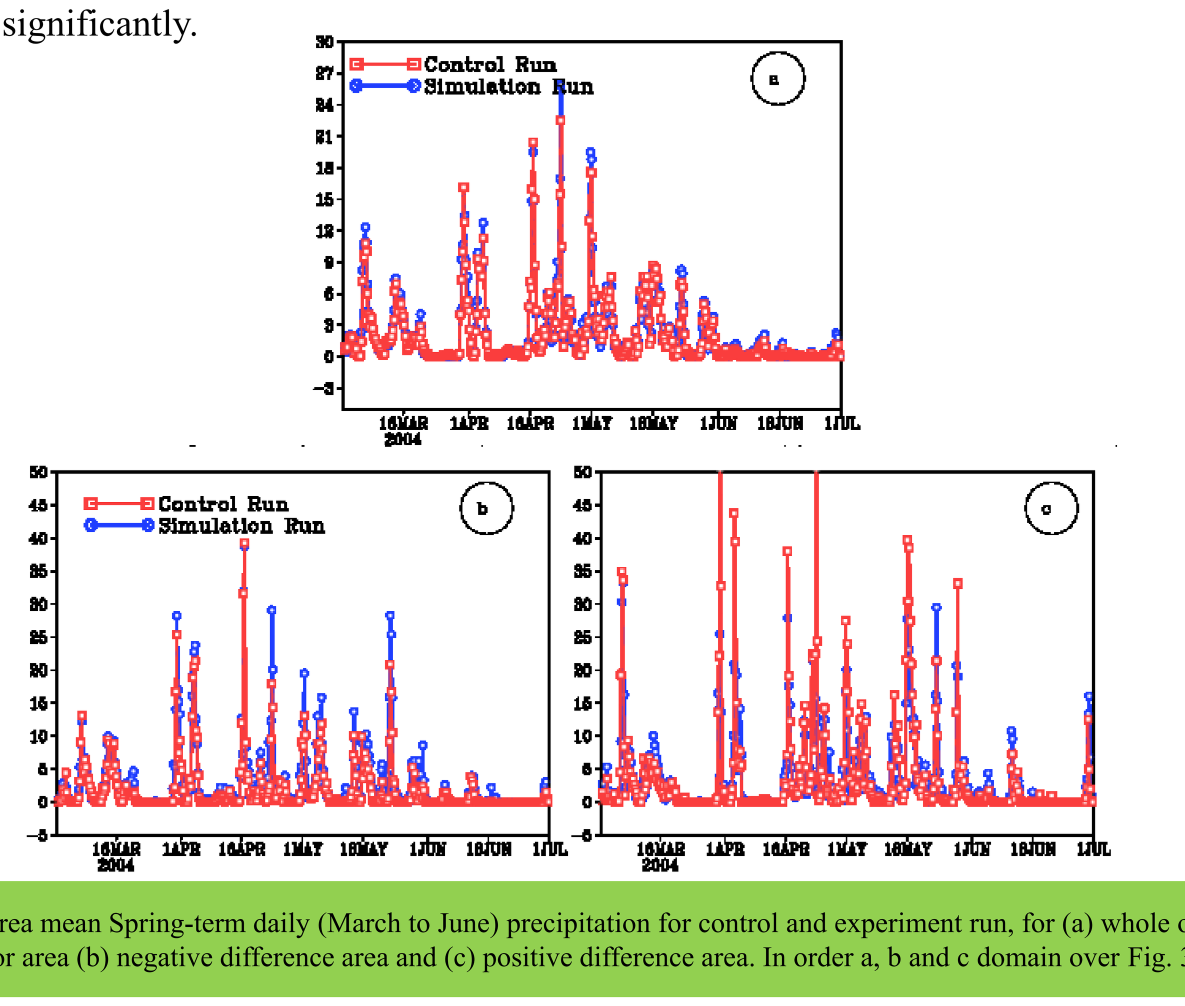

Fig. 4. Area mean Spring-term daily (March to June) precipitation for control and experiment run, for (a) whole of domain or area (b) negative difference area and (c) positive difference area. In order a, b and c domain over Fig. 3.

Fig. 5 shows distributions of different kinds of diabatic heating (local heating, horizontal and vertical advection, and total heating) in May 2004 at 870 hPa for control and simulation run. It is worth noting that the amount of heating in May was different from March. In an overview you can see the effect of heights on the heating values. It is found that observe warming occurs over the NWI Mountains at the level above. Over the NWI Mountains, the contours are correlated with the topography (Fig. 4a). After the NWI Mountains were removed in the simulation run, the values were decreased and did not follow the NWI topography and heating curves also become much more homogeneous according to latitude (Fig. 4b). Figure 4c and d indicates the horizontal advection in control and simulation runs, respectively. The maximum horizontal advection values occur over the south-west slopes of mountains and these slopes acted as heat source of energy (negative values in Fig. c). In return, the North-East slopes indicated a strong cooling due to ascent over the NWI Mountains and acted as sink source of energy (positive values in Fig. c). Removing the NWI Mountains in the simulation caused the thermal contradictions to disappear over the area (Fig. 4d). In other words, the NWI Mountains presence cause a relatively complicated pattern of horizontal advection in the lower troposphere (Dashed lines represent the heat source of energy and solid lines represent the sink source of energy). Fig. 4 shows the values of vertical advection and total heating in May 2004 at 870 hPa for both run. In fact, the thermal vertical advection from the NWI Mountains was distributed by the topography and in accordance with highlands and plain zones; it is designated as a heat and sink source of energy Fig. 4e. There is no significant pattern in the distribution of values after removing the NWI Mountains (Fig. 4f). As it will be observed later, the vertical velocity values changed when the NWI Mountains were removed from the model's topography data. In these situation, heating caused by vertical advection due to downward motions in the most areas of NWI (Dashed lines represented the heating caused by upward motion flows and solid lines represented the heating caused by downward motion flows). The Figs. 4g and 4h show that regional pattern of total heating distribution values changed when the topography were removed. In fact, thermal contradictions available in the region it depends of mountains and zones heights presence.

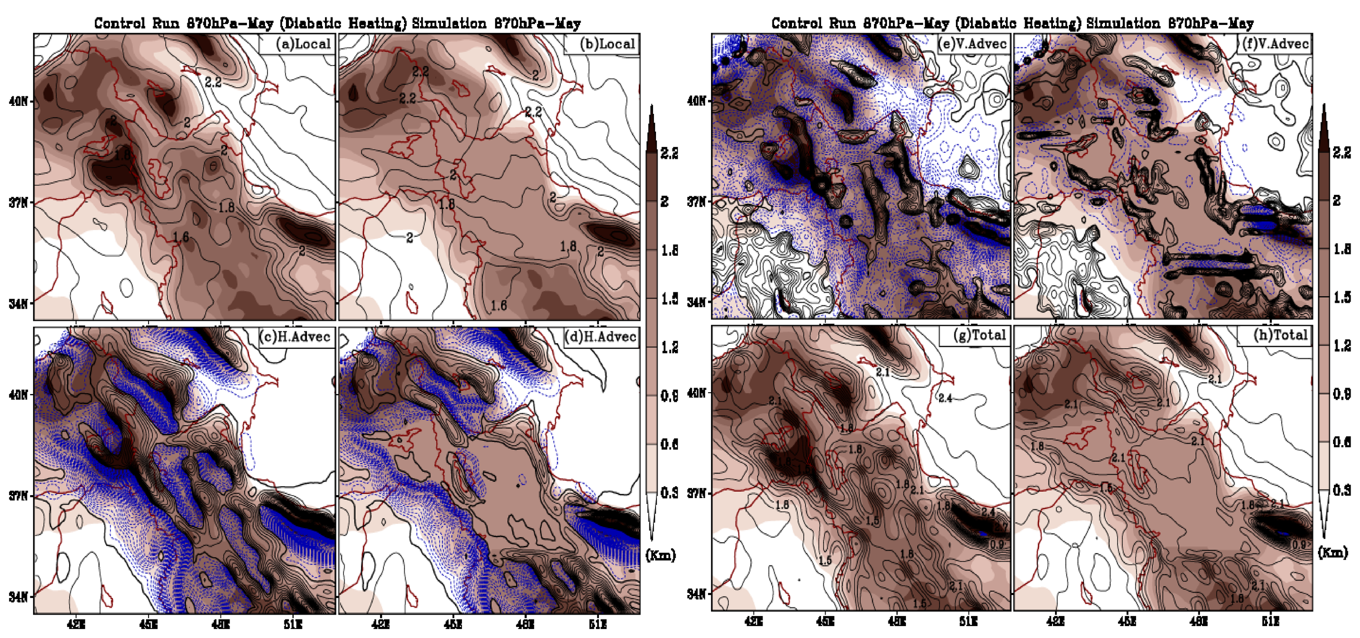

Fig.5. Distributions of different kinds of diabatic heating in May 2004 at 870 hPa. a, c, e and g control, b, d, f and h simulation run.

Conclusions

The main part of the mechanism of occurrence of springtime precipitation in NWI is the result of the existence of regional forcings, including topography and orography mechanism. So that, in terms of smoothing the topography the precipitation has decreased significantly in the NWI. Examining the diabatic heating shows that the elimination of the NWI Mountains causes a significant change in the heating values and its spatial distributions over the study area. Comparing the diabatic heating terms, the local heating has the main contribution to the total heating. In the absence of the NWI Mountains, the local heating was changed over the region. Therefore the regional forcing vanishes and changes upon removing the NWI Mountains.

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