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Attribution of temperature and precipitation changes to greenhouse gases in northwest Iran

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ABSTRACT

Increase of the greenhouse gases has a considerable effect on climatic variables changes such as temperature and precipitation. Three-dimensional models of coupled ocean–atmosphere general circulation, AOGCMs, under all emissions scenarios, are able to simulate past and future climate periods. The present study investigates the possible attribution of climate change to the increase of the greenhouse gases in northwest Iran. Interannual variability range for the long-term (1000 years) of temperature and precipitation, resulting from control run (greenhouse gas constant) CGCM3 model used for the study area in northwest Iran. Then, the range of natural climate variables was determined from two-dimensional graphs of temperature and precipitation based on two-variant normal distribution. Ultimately, the detected trends of climate variables can be compared with the natural climate variability range of the region. The results showed that in different parts of the study area, the range of natural climate variables for temperature and precipitation changes (95% probability) in the west of the study area are less than 1.8 C° and 40%, respectively. These values are less than 4 C° and 40% respectively, in the east of the study area. However, the climate variables in the most regions of the west are almost outside the range of natural climate variables in the recent years (1998–2008). The result indicates the effect of climate changes on the climatic variables for the case study in recent years.

1. Introduction

Climate change is a long-term shift in the climate of a specific location, region or planet. This phenomenon occurs when the climate of a specific area or planet is altered between two different periods of time. The shift is measured by changes in features associated with average weather, such as temperature, wind patterns and precipitation. Observations show that climate warming is conclusive (Eslamian, 2014). Recently, many scientists believe that global warming has had negative impacts on our climate (Nabibidhendi et al., 2008; Eslamian, 2014). Global warming is often misunderstood to imply that the world will warm uniformly. In fact, an increase in average global temperature will also cause the circulation of the atmosphere to change, resulting in some areas of the world warming more, others less. Some areas can even cool. Climate is influenced by a variety of factors, both human-induced and natural. A part of these factors relates to the interactions between the components of the Earth's climate system (atmosphere, hydrosphere, cryosphere, lithosphere and biosphere), such as Atlantic Multi-decadal Oscillation (AMO), Pacific Decadal Oscillation (PDO), El Niño/Southern Oscillation (ENSO) and El Nino, which can cause internal variability in time series of climatic variables (Wang and Schimel, 2003; Hegerl et al., 2007). Two important natural factors that influence climate are the Sun's energy and volcanic eruptions. Overall changes due to natural external factors and internal climatic variability within the system are called natural climate variability (Thomas et al., 2009). The increase in the carbon dioxide concentration has been the principal factor causing warming over the past 50 years. Its concentration has been building up in the Earth's atmosphere since the beginning of the industrial era in the mid-1700s, primarily due to the burning of fossil fuels (coal, oil, and natural gas) and the clearing of forests (Thomas et al., 2009). Human activities have also increased the emissions of other greenhouse gases, such as methane, nitrous oxide, and halocarbon (Denman et al., 2007; Botzen et al., 2008). These emissions are thickening the blanket of heat-trapping gases in Earth's atmosphere, causing surface temperatures to rise. According to IPCC (2007), Earth's linearly averaged surface temperature has increased

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by 0.74 C° during the period 1901–2005. Observations suggest that the warming of the 20th century global mean surface temperature has not been monotonic, even when smoothed by a 10–20-year low-pass filter (Stott, 2000; Swanson et al., 2009). Temperatures reached a relative maximum around 1940, cooled until the mid-1970s, and have warmed from that point to the present. Radioactive forcing due to solar variations, volcanoes, and aerosols have often been invoked as explanations for this non-monotonic variation (Stott, 2000; Swanson et al., 2009). Precipitation is not distributed evenly over the globe. Its average distribution is governed primarily by atmospheric circulation patterns, the availability of moisture, and surface terrain effects (Wang and Zhou, 2005; Xu et al., 2007). However, climate changes and global warming affect precipitation and extreme events such as floods and droughts (Eslamian et al., 2011a). Moreover, climate change can affect water resources, agriculture, environment, public hygiene, industry, and economy (Samadi et al., 2009; Gohari et al., 2013).

Knowledge of internal climate variability is not only necessary for climate change detection and attribution studies, but also fundamental for climate change projections and model evaluations (Collins et al., 2001; Eslamian et al., 2011b). Several studies have been performed in different parts of world about the internal climate variability (Kazadi and Kaoru, 1996; Seung et al., 2005; Zohrabi et al., 2011). Many scientists believe that increasing concentrations of carbon dioxide is the main cause of surface warming in the past 50 years (Pagano and Garen, 2005; Milly et al., 2008). This rate of warming has never been experienced in human history. Although the increase of greenhouse gases in the atmosphere causes trend in climate variables (especially temperature), its opposite is not true. This means that the existence of trend in the local climate data cannot necessarily be due to an increase of greenhouse gases. In other words, it is necessary that the relation between this trend and the increase of greenhouse gases would be demonstrated. Climate change had affected the climatic variables during the past. Therefore, it should be investigated whether the behavior of the climate system is caused by natural variability or climate change (Sridhar and Nayak, 2010). Zohrabi et al. (2011) reported the internal climatic variability and attributed it to greenhouse gases for the great Karoun River Basin located in southwest Iran. They found that the final years of the period were almost located outside the interannual climate variability range.

Iran, as a developing country, is considered as one of the greenhouse gas emitter sources due to industrial processes and increase of the population. Detection of temperature and precipitation trends has been performed by several researchers by using different statistical tests in most parts of Iran (Sabuhi and Soltani, 2009; Sohrabi et al., 2009; Tabari and Hosseinzadeh Talaee, 2011; Tabari et al., 2011; Yazdani et al., 2011; Fallah Ghalhari et al., 2012). However, the attribution of changes to the phenomenon of climate change (greenhouse gas increases) has not been taken in account for most parts of Iran. The purpose of this study is to analyze the interannual climate variability using the two-dimensional plots of temperature and precipitation and separation of this natural variability from the changes caused by greenhouse gases in northwest Iran. Hence, long-term statistics (1000 years) of temperature and precipitation, resulting from control runs (fix greenhouse gases) of the CGCM3 model were used in the study area. After identification of the natural climate variability range of the region, the changes of temperature and precipitation due to the abnormal rise in greenhouse gases in recent years were investigated.

2. Case study and data

The study area includes the Western and Eastern Azerbaijan provinces which are located in northwest Iran. The study area, which covers 432,305 km^2, encompasses about 30% of the total area of Iran. Cold and semi-arid climate prevails throughout the region with an average annual rainfall about 300–400 mm. Urmia lake, the largest lake in the Middle East and the third largest salt water lake on earth with a surface area of approximately 5200 km^2, is located between East Azerbaijan and West Azerbaijan. This area consists of three basins: Urmia lake, Aras river, and little Zab river. In this study, the annual temperature and precipitation data of thirteen stations in study area from 1968 to 2008 were used. According to the climatic classification, data verification and suitability of the record period, 13 stations in study area were selected, consisting of nine synoptic stations (Khoy, Urmia, Mahabad, Takab, Tabriz, Jolfa, Ahar, Maragheh and Mianeh), two rain gauge stations (Giahdarvan, Ghezelghebr and Galangadr) and two evaporation gauge stations (Maragheh and Pol-e-char) during a period of 40

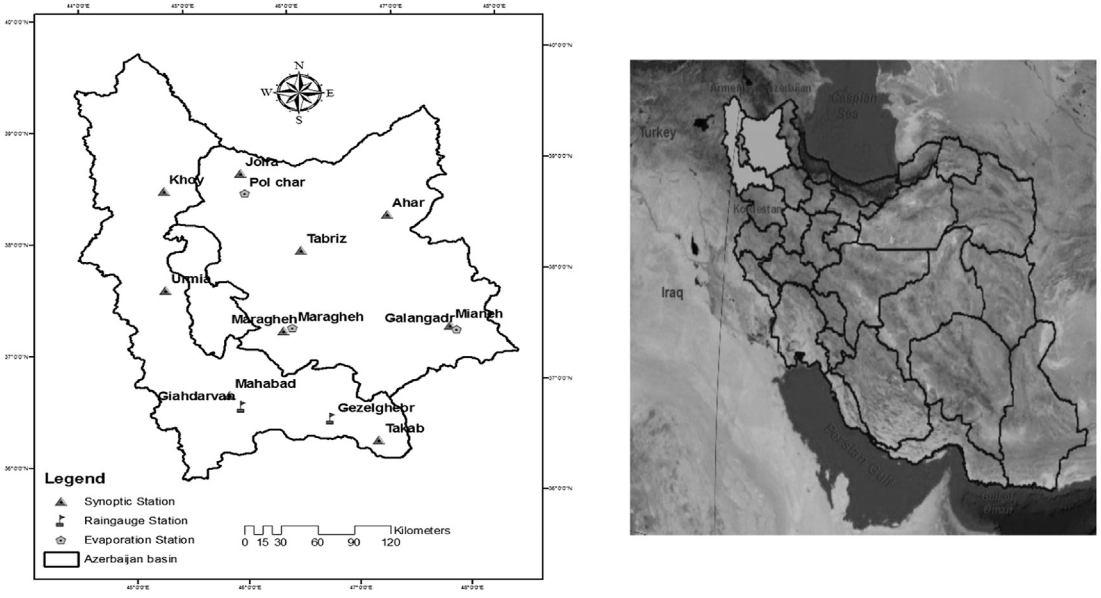

Fig. 1. Spatial distribution of the selected stations in the northwest of Iran.