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Drought or humidity oscillations? The case of coastal zone of Lebanon

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SUMMARY

There is discrepancy in classifying Lebanon according to the different climatic zones; however, it is often described as a semi-arid region. Lately, Lebanon has been witnessing climatic oscillations in the meteorological parameters. The impact of these oscillations on water sector has been reflected also on energy-food nexus. Yet, there are a number of studies obtained to identify the climate of Lebanon, and they show contradictory results; especially these studies elaborated different datasets and applied diverse methods which often modeled only on large-scale regions. Therefore, the analysis of climatic data depended on complete and long-term climatic records that can be applied to assess the existing climatic status of Lebanon, as well as to assure whether Lebanon is under drought, humidity or it is oscillating between both. This study utilized considerable datasets, from different sources including the remotely sensed systems (e.g. TRMM). These datasets were interpolated and analyzed statistically according to *De Martonne Aridity Index*. Aiming to affirm the climatic attribute of Lebanon; however, ten climatic stations were investigated. They are with representative geographic setting and diverse time series in the coastal zone of Lebanon were investigated. Even though, Lebanon is known as a semi-arid region, yet results in this study show that the studied zone does not evidence any drought, since around 70% of the investigated years are characterized by semi-humid to humid climate. This climatic figure is well pronounced since rainfall rate exceeds 900 mm, average temperature rate is about 19 °C, and snow remains for a couple of months annually.

1. Introduction

Even though Lebanon has a small area (10,452 km^2), yet it is always accounted while investigating the regional climatic assessment and models. Nevertheless, the territory of Lebanon is characterized by two mountainous ridges (i.e. Mount-Lebanon and Anti-Lebanon) which are separated by the Bekaa plain (15 km wide) and then extend parallel to the Mediterranean Sea (Fig. 1), and stands as climatic barrier restricting the cold air masses and condensate them as rainfall and snow. This makes Lebanon totally different from the neighboring regions, and it must not be included while elaborating regional hydrological and climatological assessment and modeling approaches.

Lebanon is characterized by the Mediterranean climate where four seasons occur, with warm dry summer and cool rainy winter, gradual transitional Fall and revived vegetation Spring. Generally, January is the coldest month, with temperatures from 5 °C to 10 °C, and August is the hottest month at 18 °C to 38 °C. Rainfall ranges between 650 mm on the coast and increases to 1500 mm on the crests.

The changing regime in the climatic conditions in Lebanon has been lately recognized by inhabitants rather than by the existing climatic records. Thus, the meteorological stations are few, and if they exist, they have no uniform geographic distribution, or they are with little time series data. However, new stations have been fixed lately, but they still need considerable time periods to introduce valuable datasets on time series. The lack of data often results contradictory in the assessment of the climatic regime and the consequent impact on natural resources, with a special emphasis on water resources.

Yet, the climatic regime of Lebanon is not clear and this results misunderstanding of the water cycle as a whole. Recently, water resources in Lebanon encompass abrupt decrease in the volume of water. This decrease has been reported between 50% and 60% in the last four decades, in rivers and springs fluctuating the discharge/capacity of the major lakes, as well as the rapid melting rate in the snow cover (Shaban et al., 2014a,b) due to high sunlight radiation; therefore, the influenced hydrologic regime has been reflected on groundwater which shows abrupt decline in volume and water table.

It is a paradox to rank Lebanon's climate among the aridity margins, or describe it as arid or semi-arid region, while it has sufficient water resources, and rainfall rate ranges between 650 mm and

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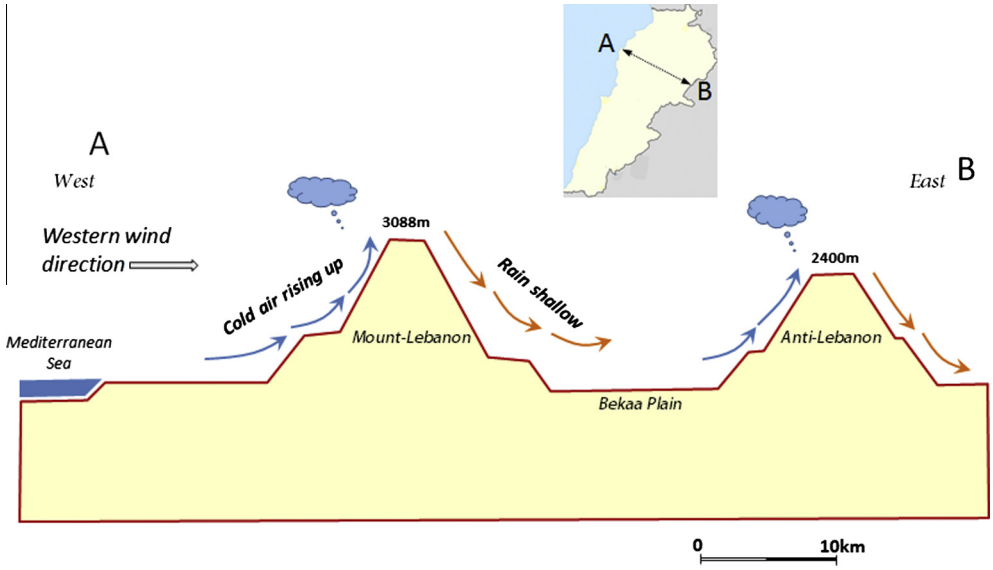

Fig. 1. Schematic figure showing the major Lebanese geomorphologic units where wind blowing and rain shadow exist.

1500 mm (averaging about 900 mm). In addition, there are several surface and subsurface water sources exist. Also, Lebanon is the only geographic region in the Middle East where snow cover remains for several months on the mountain chains covering an average area of 2500 km^2. In addition, Lebanon has 12 permanent water courses (rivers) that discharge about 3500 million m^3/year (Shaban, 2011). There are also more than 2000 major springs with an estimated discharge of 1250 million m^3/year, and the renewable groundwater reserve exceeds 1500 million m^3/year (Shaban, 2014).

There is discrepancy in classifying the global climatic zones, since it mergers regions with different topography within the same zonation. This is due to the absence of long-term and complete climatic records. Hence, there are several maps and catalogues describing the global geographic climatic regions, but the accuracy of these maps is still unfixed. This can be also considered for Lebanon where the climatic characterization is not well identified, notably there are remarkable seasonal climatic variability due to altitude of mountain ranges and their orientation. Hence, several studies described Lebanon with different climatic aspects. For example, Lebanon is described as semi-arid in the dry season to humid to sub-humid in the wet season (NC, 2011), oceanic climate during winter and a sub-tropical climate during summer (CAL, 1982), northern temperate zone and at the Mediterranean zone (CAS, 2015).

Till quite recent, there is no technical dictionary typically defines the climatic zones (e.g. arid, dry, temperate, humid, etc.). However, it is also difficult to delineate precisely the boundary between different degrees of climatic aspects. For example, what is the threshold for an area to be considered arid instead of semi-arid and what are the specific landscape and water resources manifestations of an arid versus semiarid climate?

In Lebanon, there are several studies applied on climate assessment, most of them followed ordinary statistical illustrations of curves and diagrams (Karam, 2009; Shaban, 2011; Ramadan et al., 2013; Lovallo et al., 2013). However, the application of remotely sensing in climate assessment in Lebanon can be considered in its initial steps and trials and usually accounted to the relation between climate and water (Shaban et al., 2009). Besides, there are some hydro-climatic models and scenarios applied (El-Fadel and Bou Zeid, 2001; Khawlie and Shaban, 2005; Makké-Traboulsi, 2010).

In the view of the current status; however, there must be a clear assessment for the climatic conditions in Lebanon and the climatic description must be well defined. This can be built on creditable datasets that represent long-time series and they should be complete and with minimal gaps. The idea behind this study has been created to affirm the aspect of climate of Lebanon, notably that Lebanon becomes often described as a region with drought condition.

Also, it must be well-recognized that Lebanon, with its small area, encompasses diverse climate since it winds from different directions and with warm, cold and humid types (Arkadan, 2008). In addition, Lebanon has tremendous mountainous ridges that often create turbulences in the orientation of air blowing, and thus rain shadow effect exists between the major Lebanese geomorphologic units (i.e. the Mount-Lebanon, Anti-Lebanon and the Bekaa plain) as shown in Fig. 2. Therefore, the cold air masses rising up on the mountains from west and descending air warms and picks up available moisture to the east of the mountain ridges resulting finally climatic turbulences.

According to Smiley and Zumberge (1971), aridity evokes images of dry, desert lands with sparse natural surface-water bodies and rainfall, and commonly only scant vegetation, which is adapted to a paucity of water. While drought is defined as a meteorological phenomenon that is characterized by prolonged and abnormal moisture deficiency (Palmer, 1965). Thus it is a temporary, recurring reduction in the precipitation in an area.

There are a number of formulas created to estimate and describe the climatic conditions in terms of aridity/or humidity. However, not all of them can be applied for Lebanon due to the meteorological data availability, such as the formula of aridity index obtained by UNESCO (1979) which is based on the ratio of annual precipitation and the potential evapotranspiration rates, in which the latter is calculated using the Penman (1948) formula. Thus, the lack of measures for potential evapotranspiration makes it difficult to be applied this formula to Lebanon.

Therefore, De Martonne Aridity Index (1926) can be applied since it has proved its reliability is evaluating the climatic aspects by regions, and it merely treats the major two meteorological parameters (rainfall and temperature).

2. Materials and methods

2.1. Data sources

Usually constraints exist when applying climatic and hydrologic analysis. Thus, incomplete and inconsecutive datasets of the major