

Abstract

The relationship between precipitation and mean monthly air temperature at the 850 hPa boundary level was studied in two mountain areas in Lebanon, to investigate temporal variability of precipitation and establish a weather forecast model using air surface temperature.

The European rainfall dataset E-OBS rainfall, gridded data set (v14.0) for the period of 1955-2016, with a spatial resolution of 0.25°×0.25° (v14.0), was obtained for two sites along Lebanon's Mediterranean mountains, Laqlouq region with an average elevation of the grid cell at 1550 m and Jroud Kfar Bebbine region with average elevation of the grid cell at 1490 m. The Global 30 Arc-Second Elevation Data Set (GTOPO30), a global raster Digital Elevation Model (DEM) with a horizontal grid spacing of 30 arc seconds (approximately 1 kilometer) developed by United States Geological Survey (USGS), was used for the elevation file within the gridded dataset. Besides, the Standardized Precipitation Index (SPI) was calculated for the same period at 1,3,6 and 12-month scales using the SPI Calculator (National Drought Mitigation Center of the University of Nebraska-Lincoln).

Results showed a strong negative correlation between monthly precipitation and monthly mean maximum air temperature at both locations. This trend was statistically significant at the 95% confidence level. Moreover, while SPI-1 and SPI-3 were found to be positively correlated with mean monthly maximum air temperature at the 850 hPa height ($P<0.05$), SPI-6 and SPI-12 showed negative correlations ($P<0.05$), which indicates seasonal decrease of precipitation for the onset of November-March rainfall season. We believe that spring intensification of rainfall deficit during April-May was led by unusual increase of the 850 hPa air temperature and evaporative demand. As a result, wet springs tended to be drier and this was directly related to drought occurrence experienced over Lebanon.

Keywords: 850 hPa mean monthly air temperature, Boundary level, Standardized Precipitation Index, Rainfall season, Drought.

Introduction

The 850 hPa air temperature is the temperature approximately 1.5 km above sea level (a.s.l). This level of atmospheric pressure is roughly above the atmospheric boundary layer and the underlying surface doesn't affect its temperature because diurnal variation in temperature at this level is generally negligible (Maier, 2015). As such, the 850 hPa air temperature is used to distinguish air masses and locate cold and warm fronts and in the same time indicative for cold outbreaks and snowfall (Mateling et al., 2023).

Snow clouds actually reside in the very bottom part of the troposphere, between 1000 hPa and 850 hPa. Knowing the thickness between those two levels can be helpful for snow falling alerts, as air temperature at 850 hPa is indicative for snow falling. It usually needs to be at least -5°C for snow to fall (Jeoung et al., 2020).

The Standardized Precipitation Index (SPI) is used as simple index that monitors meteorological drought by measuring how observed precipitation deviates from long-term averages over various timescales (Hayes et al., 2011). It identifies drought onset and intensity, allowing for comparison across different locations and climate (Keyantash, 2021). The purpose is to define and monitor drought and wet conditions based on precipitation data (Cerna Reyes et al., 2022). The SPI is a flexible drought index, computed over 1, 3, 6, 12, 24, or 48 months, allowing for agricultural (short-term) or hydrological (long-term) drought assessment (McKee et al., 1993).

For Lebanon, an Eastern Mediterranean country known by its mountains that raise up to 3000 m above the sea level (a.s.l), the 850 hPa air temperature is only 500 m higher into the atmosphere than the 1000 m height a.s.l, where a considerable fraction of the rural population live. As such, if we know air temperature at the 850 hPa height (1550 m a.s.l), we only need to add 0.66 °C for each 100 m decrease in altitude to account for the snowfall line, also called freezing line (FL) (Pozo et al., 2023). It usually needs to be at least -4 °C at the 850 hPa level for snow to fall at 1000 m height. As a result, the freezing line (FL) is established to warn the population on frost-derived risks either on the roads or as damages to agriculture.

The approach used in this study consists in bringing the 850 hPa air temperature to the surface instead of using the surface maximum temperature. The objectives are to (i) provide accurate precipitation forecasts and snow alerts in Lebanon's mountain area based on the 850 hPa air temperature, (ii) investigate temporal variability of precipitation and deduce the impact of climate variability on Lebanon's society and environment and improve understanding of drought occurrence.

Material and Methods

The study area is located on the western slopes of Mount-Lebanon. Two sites were chosen along Lebanon's Mediterranean mountains, the first in Laqlouq (LAQ) with an average elevation of the grid cell at 1550 m and the second in Jroud Kfar Bebbine (JRD) with an average elevation of the grid cell at 1490 m (Figure 1a).

Weather parameters including maximum and minimum air temperatures, relative humidity, wind speed and direction at 10 m height were obtained from an automatic weather station (AWS) that was installed in a pilot weather park in Zaarour at 1550 m a.s.l. Weather forecasts at 4 day-interval (AWS) that was installed in a pilot weather park in Zaarour, Lebanon (<http://www.snow-forecast.com>), which are updated at hourly basis (Figure 1b). This weather forecast service provides 850 hPa air temperature as an indicator of near-surface temperature during persistent precipitation events, particularly when the 850 hPa layer is close to saturation.

The methodology of work consisted of studying the correlation between monthly precipitation and monthly mean maximum air temperature at these two typical locations of the 850 hPa height. The European E-OBS gridded data set (v14.0) for the period of 1955-2016 with a spatial resolution of 0.25°×0.25° (version 14.0) was also obtained for the scope of this study.

Data collected consisted of daily maximum temperature (TX) and daily precipitation sum (RR). These data were representative of two different sites namely Laqlouq region (LAQ) with an average elevation of the grid cell at 1550 m (central coordinates: lat. 34.133665° and long. 35.846516°), and Jroud Kfar Bebbine region (JRD) with average elevation of the grid cell at 1490 m (central coordinates: lat. 34.383° and long. 36.126°). It is to be noted that the Global 30 Arc-Second Elevation Data Set (GTOPO30), a global raster Digital Elevation Model (DEM) with a horizontal grid spacing of 30 arc seconds (approximately 1 kilometer) developed by USGS was used for the elevation file within the gridded dataset.

Moreover, the Standardized Precipitation Index was calculated at 1,3,6 and 12-month scales using monthly precipitation data of the same period by means of the SPI Calculator (National Drought Mitigation Center of the University of Nebraska-Lincoln) and correlated to mean monthly maximum air temperature at the two studied locations. Significances were tested using statistical methods. As such, the Standardized Precipitation Index at different scales (SPI-1, SPI-3, SPI-6 and SPI-12) was calculated. Time series of Monthly precipitation and average monthly maximum air temperature were acquired from the Global Precipitation Climatology Centre database (GPCC) for the years 1951 through 2010 mainly due to the lack of periodical reliable data from actual stations across Lebanon over the required period of time. More specifically, the employed dataset was developed within the research project VASCLimO (Variability Analysis of Surface Climate Observations) in the form of gridded monthly precipitation with a spatial resolution of 0.5°×0.5°. This dataset subdivided the total surface of Lebanon into distinct GPCC datasets with four center points located within the country. In addition, the European rainfall dataset E-OBS rainfall gridded data set (v12.0) released in October 2015) for the period of 1950 throughout 2014 with a spatial resolution of 0.5°×0.5° was obtained for this study. The grid cells of this dataset and their center points coincide with those from the VASCLimO dataset.

Results and Discussion

Results showed a strong negative correlation between monthly precipitation and monthly mean maximum air temperature at both locations LAQ and JRD. This trend was statistically significant at the 95% confidence level ($P<0.05$) (Figures 2a & 2b). Results show that the evolution of temperature at the standard isobaric level of 850 hPa pointed at strong warming in the last 30 years (1986-2016). Moreover, it was observed that during the period 1986-2016 the maximum temperatures at the 850 hPa level were higher by 1°C than during the period of 1955-1985. The heating at the analyzed isobaric level overlaps the growing of ground temperature, analyzed the medium annual temperature in the period 1955-2016.

Moreover, while SPI-1 and SPI-3 were found to be positively correlated with mean monthly maximum air temperature at the 850 hPa height ($P<0.05$), SPI-12 showed negative correlations ($P<0.05$), thus indicating seasonal decrease of precipitation for the onset of November-March rainfall season (Figures 3a & 3b). We believe that spring intensification of rainfall deficit during April-May was led by unusual increase of the 850 hPa air temperature and evaporative demand. As a result, wet springs tended to be drier and this was directly related to drought occurrence experienced over Lebanon.

On the other hand, the 850 hPa air temperature (1550 m height) was forecasted to be -2 °C from the cited information source. An accurate height estimation will give us the line of snow falling, as above marked in Figure 1b. For more precision, we have established that the forecasted 850 hPa temperature is -2 °C and we have also established that the 850 hPa height is at an altitude of 1550 m above sea level, we took off 0.66 °C for each 100 meters below 1550 m until we got the freezing line (FL, °C). The freezing line was at 1000 m height, above and sometimes and reaches 500 m height, where approximately 50% of the population live, and where most of schools are located.

Conclusions

The 850 hPa isobaric surface temperature was shown to be a good indicator of air temperature evolution. This level of atmospheric pressure is roughly above the atmospheric boundary layer and the underlying surface doesn't affect its temperature, mainly because diurnal variations of T °C at this level are negligible. Concerning the evolution of temperature at this standard isobaric level, a strong correlation with monthly Standardized Precipitation Index at the two studied sites was obtained. Wet springs tended to be drier and this was directly related to drought occurrence over the high altitudes in Lebanon. We intend to complement this study by expanding the examination of the relationships between precipitation and mean monthly maximum air temperature to other locations of the 850 hPa height along Lebanon's Mediterranean mountain's chain.

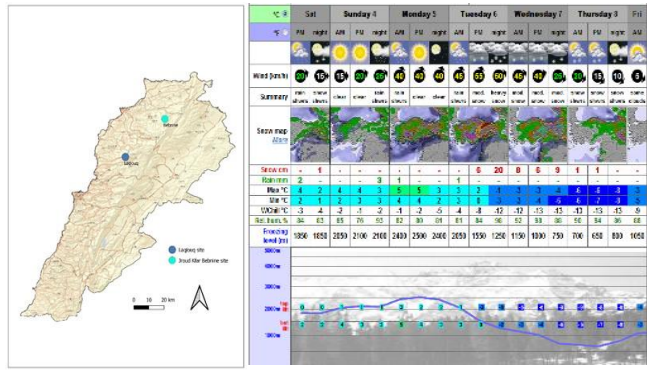


Figure 1: Location of the two sites (1a - Left) and an example of weather forecast (1b - Right) at 850 hPa height along Lebanon's mountains (1550 m height) (source: <http://www.snow-forecast.com/resorts/Zaarour/6day/bot>)

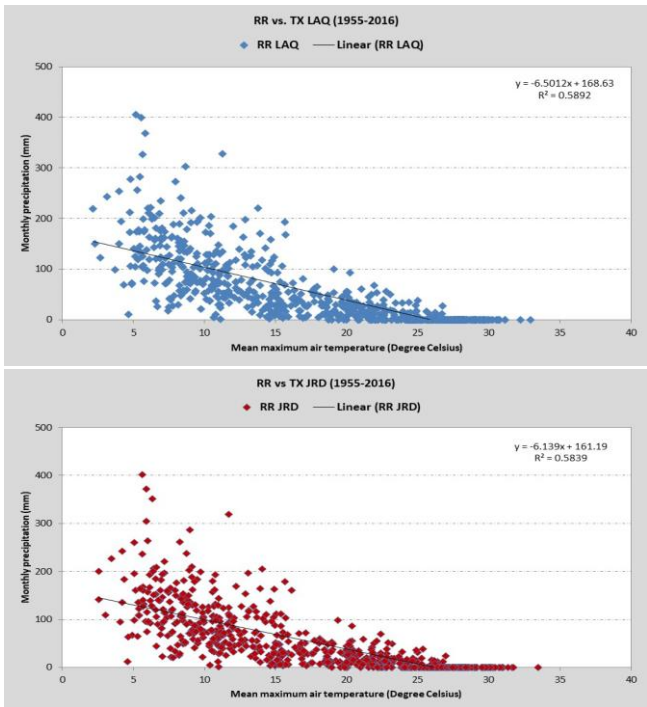


Figure 2: Relationship between monthly precipitation and mean monthly air temperature at the two sites (Above 2a - LAQ, Below 2b - JRD)

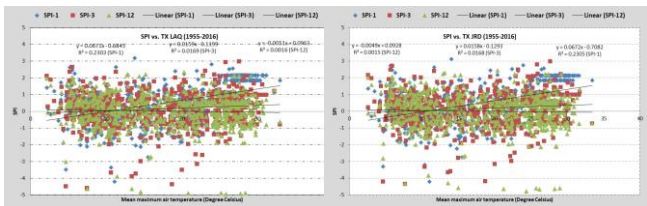


Figure 3: Relationship between SPI (1, 3, 12) and mean monthly maximum air temperature at the two sites (Left 3a - LAQ; Right 3b - JRD)

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