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Analysis Change of Snow Depth by Using ECMWF for Northern Iraq

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Abstract

The snow depth (SD) is the cumulative amount of snow currently on the mountain. The SD is measured using two methods; the First is by taking basic samples, and the second method is by using a snow pillow. SD and snow cover are determined by atmospheric and land surface conditions. The rates of precipitation, deposition, and condensation, together with the magnitudes of the turbulent transfer of heat and moisture, radiative exchange, and air movement, all contribute to them. SD increased as a function of temperatures falling with increasing land elevation. ECMWF was the main source of data - the latest version ERA5 - mapping based on satellite and ground station network data. The global SD data was also available, selected region Middle East (ME) for monthly, long period (1990 -2022). In fact, the results indicate that the SD decreases rapidly over time, possibly due to the impact of climate change. There are three areas that have special patterns with coherent and synchronized that are obviously more sensitive toward climate system (SD). Although these three regions were scattered but have the same SD. These regions are located in different countries (southern Turkey, northern Iraq, and western Iran), which is a mountain range (Zagros).

Keywords: *Snow depth, ECWMF, Middle East, Iraq.*

1. Introduction

Snow is made up of individual ice crystals that grow while suspended in the atmosphere - usually within clouds - and then fall off and accumulate on the ground. Small ice crystals in clouds bind with each other to make snowflakes. The crystals will eventually be packed so densely that they are heavy enough to fall to the ground. Snowflakes will melt at their edges and fuse together to form large flakes as they fall through moist air that is slightly warmer than 0°C [1]. Falling snow begins to melt once the temperature rises above freezing, but as the melting process begins, the air around the snowflake is cooled. Snowfall can be defined as "light," "moderate," or "heavy." When combined with strong winds, falling snow can cause blizzards and drifts. If it is warmer than 2°C, the snowflake will melt and fall as sleet instead of snow, and if it is warmer, it will be rain[2]. There are many of studies in the analysis of monthly and annual mean for snow cover distribution as; **(**STURM, et al., 2009) where Snow Water Equivalent (SWE) uses Snow

depth and climate classes. The SWE values were calculated within 68 cm decades at 37 sites throughout the United States, Canada, and Switzerland. The comparison between estimating SWE using the Numerical model was shown to be equivalent to a ratability of repeated SWE measurements at one site. The technique may therefore allow a more efficient but indirect sampling case[3]. Turkey studies (BALTACI, et al., 2019) long-term variability and trends in winter snowfall resulted in higher rates of sickle cell disease during the winter with positive patterns in the eastern Atlantic/western Russia. High-pressure (>5 cm) daily composite maps of sea level pressure show that strong northeasterly flows enable penetration of cold polar air into the EAR due to the interaction between a high-pressure center in Siberia over Europe and a low-pressure center over the Caspian Sea[4]. (LIVENS, et al., 2019) notice that observed variation in snow depth for northern hemisphere mountains from space. demonstrated the ability of Sentinel-1 to map snow depth in Northern Hemisphere mountains at 1 square kilometer resolution using an experimental change detection approach, exemplified by the variation of snow depths between 2017 and 2018 in the American Sierra Nevada and the European Alps. With Sentinel-1 guaranteed to last through 2030 and likely beyond, these results lay a foundation for estimating the long-term vulnerability of mountain snow water resources to climate change[5]. More than 17 models of snow were used by (AMIHAESEI, et al., 2020) to estimate snow depth and snow water equivalent (SWE), for several mountain meteorological stations from Romania. The model uses air temperature as the sole indicator to quantify energy exchange across the air-snow interface. It has been observed that depending on the altitude station, the estimated values have different errors. The strong correlation between the estimate and the observed values for (Sinaia, Palea) station while the correlation was weaker for (Vf. Omo) station. Regarding the SD values, little difference found out between the sample and observation data. The model was confidence validates to applied for several weather stations in Romania[6]. (OLEFS, et al., 2020) carried out the changes in snow depth in Austria, snow cover duration(SCD), and snowmaking conditions were found for the years 1961–2020 - a model-based approach. The results indicate a clear height dependence of the relative decreases 55% to 0% (SCD). Changes detected by major transitions occur in HS in the 1970s and late 1980s. Due to the heterogeneous snow-making infrastructures, the results are not suitable for direct interpretation towards snow reliability of individual Austrian ski resorts but are relevant for all activities that rely heavily on natural snow as well as for projections of future snow conditions and climate impact research [7]. Chinese research (GAO, et al., 2021) snow depth, snow water equivalent distribution, and anisotropy were studied in the Irtysh River basin from 2000 to 2018. ERA-Interim was used as driving data to simulate dynamic suspension in snow depth and snow water equivalent (SWE). using the Noah-MP land surface model, results were compared and snow depth and snow water equivalent were found that higher value in the north of the basin than in the south. The mean snow depth, snow water equivalent, snow days, and time to start of snow accumulation (STSA) in the basin did not change significantly over the study period, but the time to end of snow melt was significantly ahead[8]. (AL-KHUDAIRI & AL-TAMIMI, 2021) analyzed the relationship between LST indices and vegetation cover using Landsat 8 data in Dohuk Governorate, Iraq. The results showed a strong positive relationship between the vegetation cover indicators during the four seasons and the strongest correlation in the spring season[9]. Recently studied by (DAI, et al., 2022) snow depth or snow water equivalent was estimated from space. Satellite remote sensing is widely used to estimate snow depth and snow water equivalent (SWE) which are key factors in global and regional climate and hydrological systems, and snow depth retrieval in mountainous region was found to be very challenging for satellite remote sensing due to the

complex topography. With the increased number of freely available Synthetic Aperture Radar (SAR) data, new future passive and active microwave remote-sensing combing methods are needed to improve the accuracy of snow depth retrieval in mountainous regions[10]. The results showed that Basra was higher by satellite annually compared to four selective cities in Iraq, through a study conducted by the researcher (BASHIR, 2022) when analyzing the annual trends of surface air temperatures for some stations over Iraq [11].(AL-SAMAEEAI et al., 2022) studied the estimation of the daily maximum air temperature for the city of Baghdad using multiple linear regression. It is found that the relationship between *T*max and *T*min has a high positive correlation[12].

1. Data and Methods

European Center for Medium Range Weather Forecasts (ECWMF) was main source of data that available integration data. ERA5 is the fifth generation ECWMF atmospheric reanalysis of the global climate. Selected region for (ME) (40 to 10 °N and 30 to 60 °E), monthly data for depth snow. This data was converted to annual mean to focused on seasonally effects. The data were processed by panoply and drawn through the new version of panoply as shown Figure 1.

Figure 1. Map of Middle East region[13].

The location of Iraq in relation to the Middle East, where Iraq is located in western Asia. It is bordered by Turkey to the north, Iran to the east, the Arabian Gulf, Kuwait to the southeast, Saudi Arabia to the south, Jordan to the southwest, and Syria to the west.

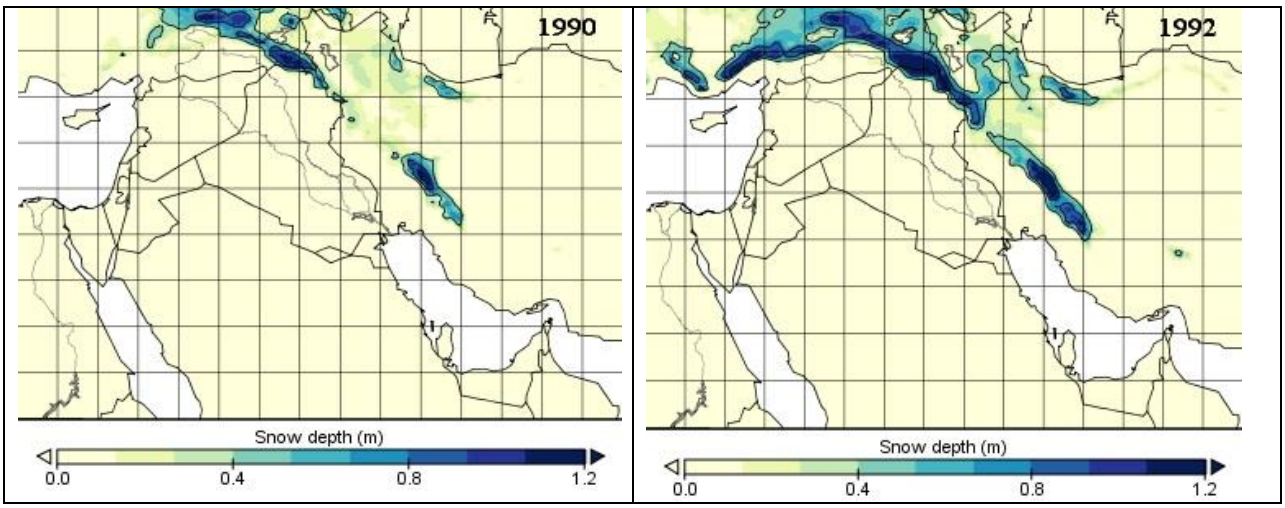
The mountainous region occupies 6% of the area of Iraq, which is about (92 thousand) square kilometers, starting from the south of Kirkuk represented by Mount Hamren as shown in Table 1, and extending east to Iran and west to Syria and from the north to Turkey. The mountainous region is located in the northern and northeastern part of Iraq. The climate in Iraq varies greatly according to the geographical area. The hot desert climate prevails in the southern regions of the country, while the continental climate prevails in the northern, mountainous and eastern regions, and is characterized by mild summers and very cold winters. The temperatures drop and range from -20°C to -10°C in the winter. The amounts of rain and snow falling vary from one region to another. As for the western regions, a very dry and hot desert climate prevails.

Table 1. Longitude, latitude and elevations above sea level for study stations in Iraq.

Study Stations	Longitude (°E)	Latitude (°N)	Elevations above sea level in meter
Sulaymaniyah	45.43	35.55	882
Duhok	43.0	36.86	565
Zakho	42.69	37.13	440
Erbil	44.0	36.19	420
International borders	42.8	37.2	1200

2. Result and discussion

An accurate representation of the times and locations of snowfall function to snow depth is a significant for to the hydrological cycle and water availability in the context sustainability development. Relatively thin ice is highly sensitive to climate change, and has a significant impact on atmospheric circulation both regionally and globally. Through analysis, notice that the snow depth is divided into three main areas (high, medium, and shallow) SD. For high SD that illustrated in Figure 2, there is a great variation in SD in the first decade, as there was a highest SD during the years (1992, 1993, and 1995) after that found recession period for 6 years. Unfortunately, this highest SD didn't repeat again. While second decade found the highest SD during the years (2002, 2003, and 2004), another recension attacked same region, but this time for 8 years. As for the last two decades, there is a highest SD that illustrated in Figure 3 in the years (2013, 2016, 2017, and 2019). As for the rest of the years, the depth is medium and relatively weak. These results indicated to the SD rapidly decreased with time, maybe because of the effect of climate change. There are three areas have special pattern with coherent and synchronized that obviously more sensitive toward climate system (SD). Although these three regions were scattered but have same SD. These regions each one located in each country (southern Turkey, northern Iraq, and western Iran), which is a mountain range (Zagros).



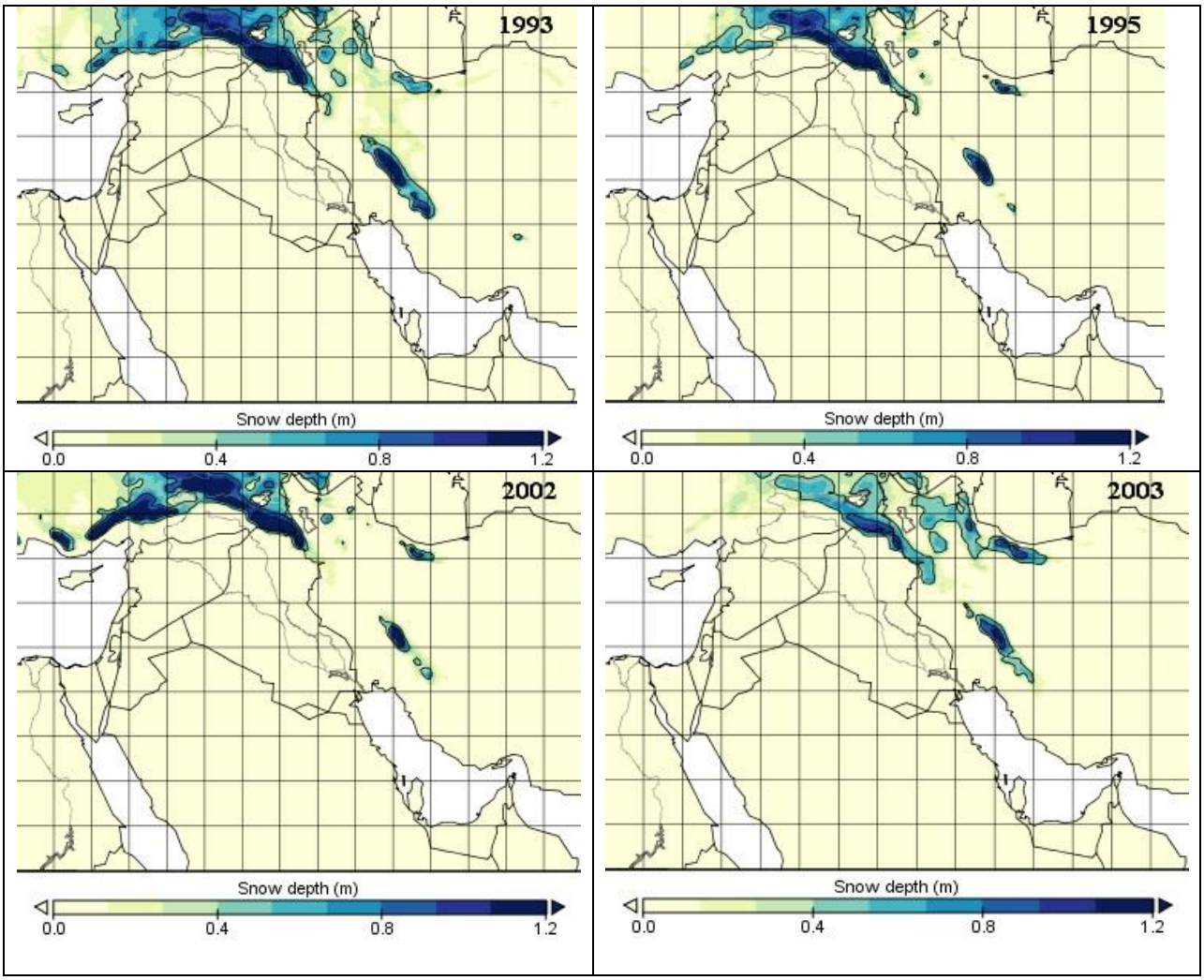
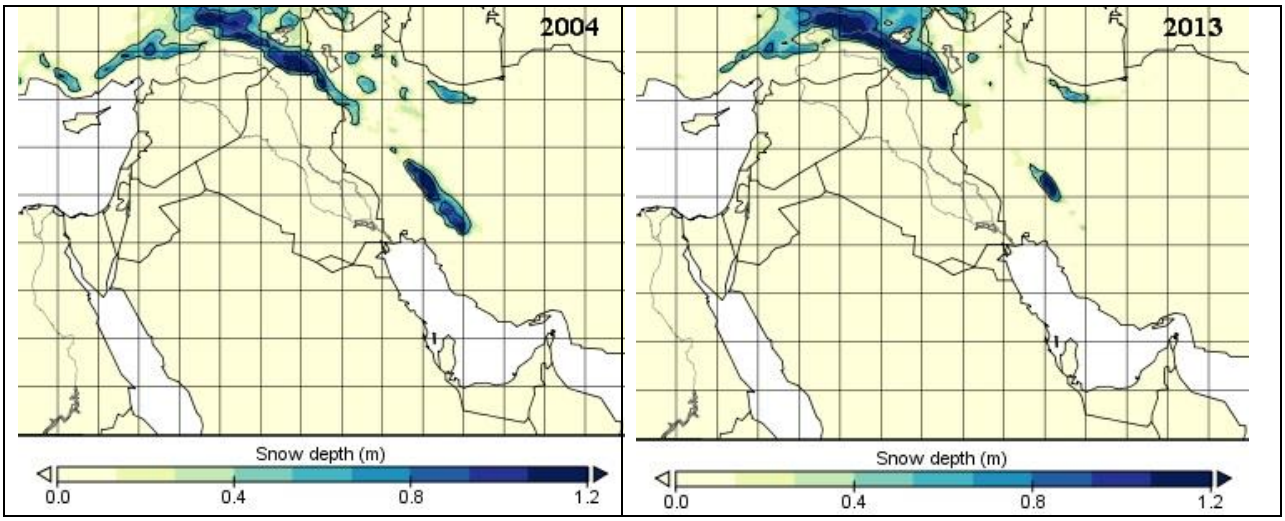


Figure 2. highest SD for the period (1990_2022).



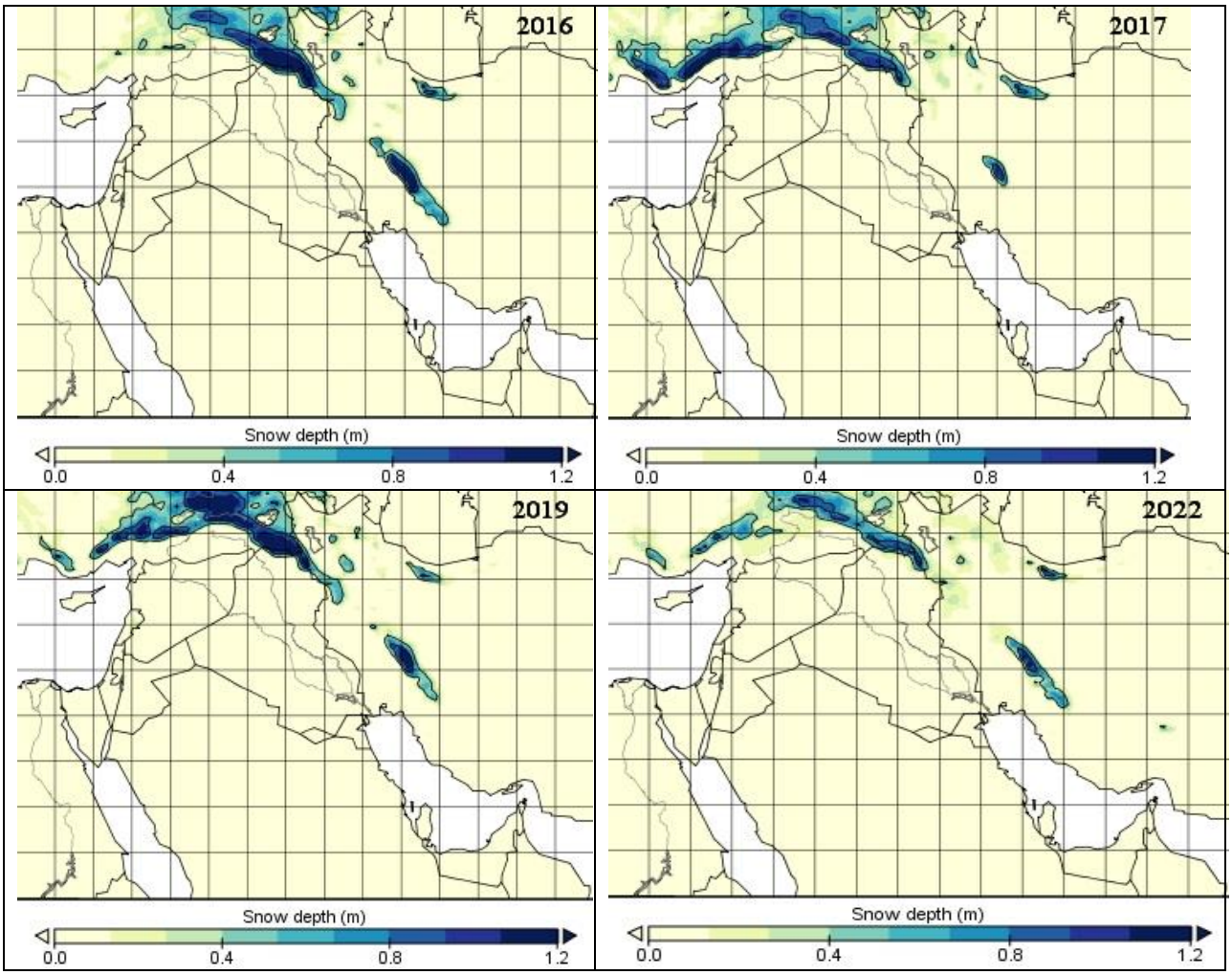


Figure 3. highest SD for the period (1990_2022).

Through Figure 4, presents the SD was relatively low in the years (2005, 2006, and 2010) and that the region's area was gradually shrinking in compare with Figure 1. The SD in the remain study years was relatively poor sometimes nonexistent, which has a detrimental impact on the reduction of the water generated during melting.

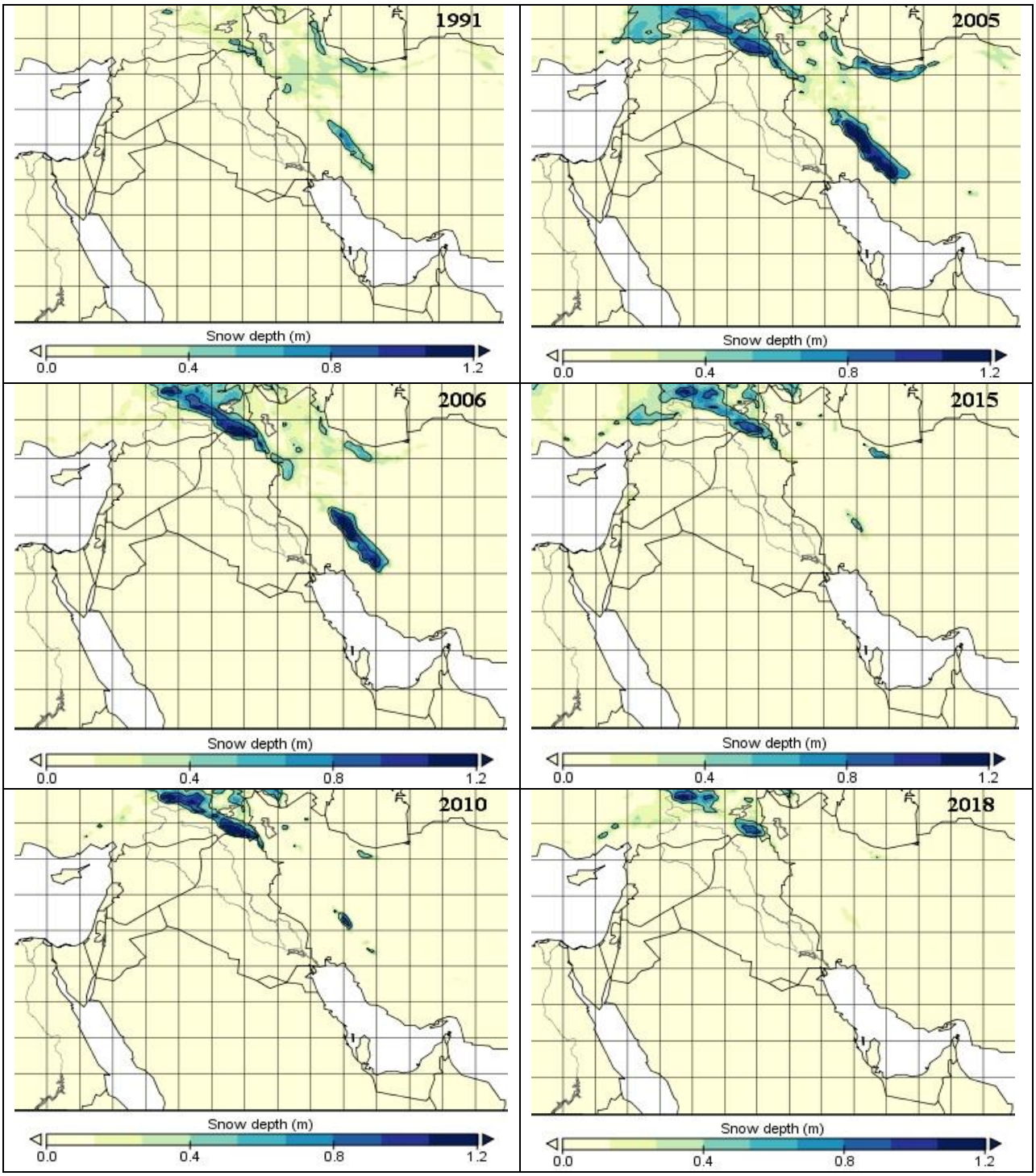


Figure 4. Middle and Weak SD for the period (1990_2022).

The time series for the point Iraqi – Turkey border that located at (37.2 N, 42.8 E) represented as a high amount of snow depth. The highest value found out in 1992 was (0.36 m), this refers to strong linked with El Nino event recorded (-2.9) of SOI (southern Oscillation Index). Obviously from figure 5 that fluctuations of snow depth peak were unregular, therefore classify to the annual scale to three periods. First period was with high peaks frequent three peaks ;1992, 1994,

and (1997 -1998). While the second decade had two peaks with different amplitude (2003,2007) the recorded (0.06, 0.03 m) respectively. The last decade had two small peaks in (2013 - 2014), (2016 -2017) ware snow depth peaks for all these years were (0.03m). these results shown significant role of climate change that effect on this parameter especially the topography of that region is moutons that had less snow depth recently years to face a crisis problem of water security in Iraq.

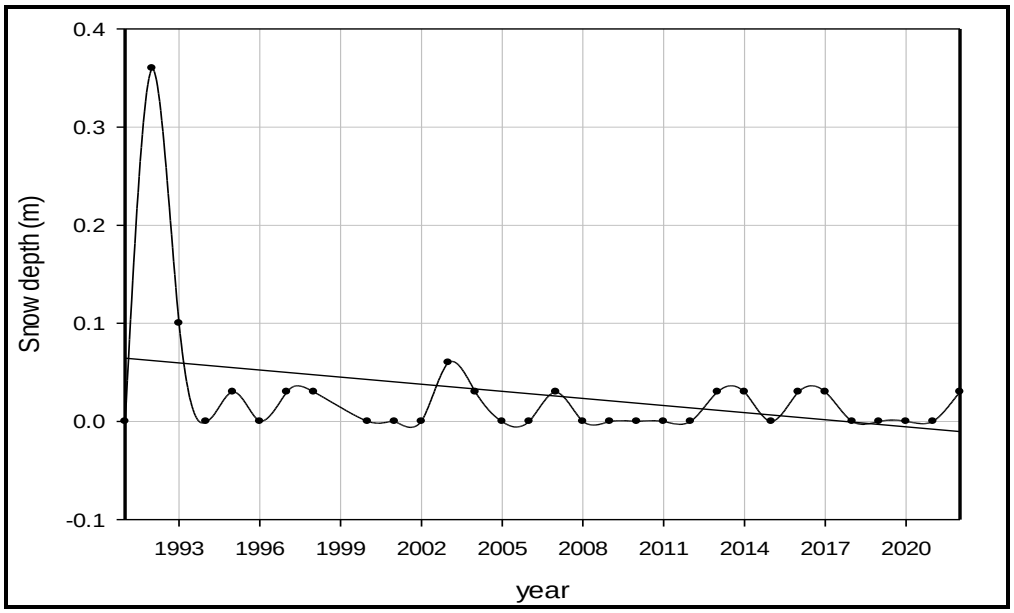


Figure 5. Time series of snow depth at (lat.37.2N, 42.8 E), in Iraq.

Conclusions

This study target was the SD for spatial distribution to provide more information about available variable as part of hydrology cycle. The results shown that SD decreased with a time series last decade. this because the effect of global warming that had less snow depth as part of water resources problem in Iraq. Obviously that fluctuations of snow depth peak were unregular, therefore classify to the annual scale to three periods. First period was with high peaks frequent three peaks ;1992, 1994, and (1997 -1998). While the second decade had two peaks with different amplitude (2003,2007) the recorded (0.06, 0.03 m) respectively. The last decade had two small peaks in (2013 - 2014), (2016 -2017) ware snow depth peaks for all these years were (0.03m). these results shown significant role of climate change that effect on this parameter especially the topography of that region is moutons that had less snow depth recently years to face a crisis problem of water security in Iraq. There are three places with unique patterns that are coordinated and synchronized and are plainly more sensitive to the climatic system. Despite being dispersed, these three areas share the same SD. There is a mountain range called the Zagros in each of these places, which are in the countries of southern Turkey, northern Iraq, and western Iran.

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