Al-Mustansiriyah Journal of Science
ISSN: 1814-635X (print), ISSN:2521-3520 (online) Volume 33, Issue 4, 2022 DOI: http://doi.org/10.23851/mjs.v33i4.1161

Research Article Open Access

Evaluation of Geopotential Height at 500 hPa with Rainfall Events: A Case Study of Iraq

Mohammed Abdul Raheem Jabbar [1]*, Ahmad S. Hassan[2]

[1]Iraqi Meteorological Organization and Seismology, Baghdad, IRAQ.
[2]Department of Atmospheric Sciences, College of Science, Mustansiriyah University, Baghdad, IRAQ.

*Correspondent contact: mohammeda198383@gmail.com

Article Info

Received
29/05/2022

Accepted
23/07/2022

Published
30/12/2022

ABSTRACT

The geopotential height at 500 hPa is a key factor in determining the weather and climate conditions around the world. This paper aims to study the effect of 500 hPa geopotential height in Iraq weather from a synoptic perspective and evaluation the variation at 500hpa geopotential height. On (26-29 January 2013), a case of atmospheric instability affected Iraq, where a heavy amount of rain fell over Iraq on 28 January 2013, the amount of rain that fell on Kirkuk was about (72.2mm). The result showed that when the upper-level trough stretches from Europe towards the Mediterranean, it will enhance surface low pressure. In addition, the advection of moisture from lower latitudes resulted in a situation of instability that brought severe rain to Iraq. during this period the value of geopotential height decreased sharply. The decrease in the value of geopotential height is an indicator of turbulent weather when compared to surrounding regions.

KEYWORDS: 500 hpa; geopotential height; rainfall; trough; Iraq.

الخلاصة

يعتبر الارتفاع الجهدي عند مستوى (**500**) هكتوباسكال عاملاً رئيسيًا في تحديد أحوال الطقس والمناخ حول العالم. تهدف هذه الدراسة الى دراسة تاثير الارتفاع الجهدي عند مستوى (**500**) هكتوباسكال. في (**26-29** كانون الثاني **2013**) حالة من عدم الاستقرارية الجوية اثرت على العراق ، تساقطت كمية كبيرة من الأمطار على العراق في **28** كانون الثاني **2013** حيث بلغت كمية الأمطار التي سقطت على كركوك حوالي (**72.2** ملم). أظهرت النتيجة أنه عندما يمتد الحوض العلوي من أوروبا باتجاه البحر المتوسط ، فإنه سيعزز الضغط المنخفض على السطح. بالإضافة إلى ذلك ، أدى انتقال الرطوبة من خطوط العروض المنخفضة إلى حالة من عدم الاستقرار التي أدت إلى هطول أمطار غزيرة على العراق. خلال هذا الفترة ، انخفضت قيمة الارتفاع الجهدي بشكل حاد. يعتبر الانخفاض في قيمة الارتفاع الجهدي مؤشرا على الطقس المضطرب بالمقارنة مع المناطق المحيطة.

INTRODUCTION

Iraq is situated at the crossroads of the Middle East in south-west Asia between latitudes 29° 5' and 37° 22' N and longitudes 38° 45' and 48° 45' E [1]. Iraq is bordered by Turkey to the north, Iran to the east, Kuwait, and Saudi Arabia to the south, while the west part of Iraq is shared with Jordan and Syria [2]. The climate of Iraq is arid to semiarid, The rain starts from October through April [3]. There is a gradient in rainfall, where the annual rainfall in northeastern mountains exceeds 900mm and in the southern desert about 100mm [4]. Surface weather systems that cause rainfall in Iraq are Mediterranean low pressure and Sudanese low pressure [5]. Rainfall over Iraq is comparable to rainfall in mid-latitudes in that it is mostly influenced by upper-level weather patterns (trough, cut-off low, rex block) that boost the weather system at the surface [6].

Due to global warming, there is a change in the behavior of the synoptic system in the middle east, where there is a decrease in the mid-latitude cyclone [7]. South West Asia countries face a downward trend in annual rainfall, where Iraq is the most affected country and can be regarded as in crisis due to the lack of rainfall [8]. Heavy rainstorms can strike anywhere in the world and last for days, causing widespread flooding, infrastructure damage, and even death [9].

The geopotential height at 500 hPa is a key factor in determining the weather and climate conditions around the world [10]. D. Q. Hmood Abd and A. K. Abdul kareem 2020 [11] studied the rainfall over Iraq from 2007 to 2018 and found that the upper-level depression was the primary cause of significant rainfall over Iraq. Mutar *et al* 2021 [12] investigated the torrential rain that fell over Iraq on (27-29 January 2019), they point out that disturbances at 500 hPa play an important role in the formation of the cyclone at the surface, which increases instability and leads to convective clouds that produce heavy rainfall.

Al-Nassar *et al* 2020 [13] studied the extreme precipitation event in Iraq during the years of (2005-2016), They found out that severe rainfall was linked to a 500 hPa geopotential height disturbance and the transport of warm, moist air from lower latitudes. Jafaar.I and Kadhum. H 2019 [14] studied the dynamic of extreme rainfall events across Iraq, they showed that the disturbance at 500hpa geopotential height was a crucial factor in the stormy weather over Iraq. A.M. Al-Lami *et al.* 2021 [15] studied the Spatiotemporal analysis of extreme rainfall indices in Iraq from 1981 to 2017, the result showed that the highest rainfall total indices were found in the northwestern region, while the lowest were found in the western and southern regions. Al salihi *et al.* 2014 [16] analyzed the trend of rainfall in Iraq for 36 meteorological stations from 1981 to 2010, and found out a negative trend in annual rainfall for the majority of stations.

Khidher, S. A., & Pilesjö, P. 2015 [17] studied the North Atlantic Oscillation (NAO) Impact on the Climate of Iraq, they found that rainfall in Iraq rises during the NAO negative phase and falls during the positive phase. Hunt *et al.* 2021 [18] looked at the devastating floods that hit northern India in 2013, they showed that the combination of the upper air trough and the powerful monsoon low-pressure system was principally responsible for the extreme rainfall events. Almazroui *et al* 2016 [19] studied the link between disturbances at 500 hPa geopotential height and rainfall in Saudi Arabia during the wet season. The study pointed out that during stormy weather, the average geopotential height is between 5500 and 5600 geopotential meters. Deng, Liping, *et al.* 2015 [20] used the model of weather research and forecasting to investigate heavy rainfall occurrence over Saudi Arabia, they found out that the penetration of a trough to the red sea area plays an important role in enabling low-level advection of humid air from the red sea, resulting in extreme rainfall events. Yang Ai1 & Weihong Qian 2020 [21] examined the extreme rainfall amount hit japan in July 2018 which cause a tremendous social and economic consequences, they found the trough at the upper level with advection of moist air at the low level was the main cause of this catastrophe.

MATERIALS AND METHODS

To better comprehend the relationship between upper-level and surface weather variables, weather patterns at 500 hPa were investigated. For each day of the events, a surface pressure map to illustrate weather system at the surface, in addition to other maps, surface relative humidity map, surface vector winds maps, and precipitation rate map. The synoptic maps for surface and upper-levels were obtained from the National Oceanica and Atmospheric Administration (NOAA) [22] which offers a large collection of archived maps for the entire world. The selected maps cover the domain of longitudes 10°E to 70°E and latitudes 10°N to 50°N. The value of geopotential height at 500hpa in meters used in this study for eight station as shown in Table 1 was obtained from the European Center for Medium-Range weather Forecast (ECMWF) ERA-Interim [23]. The satellite image obtained from NASA [24].

Table 1. The geographical location for stations used in this study.

Station	Elevation (m)	Latitude°	longitude°
Mosul	223	36.19	43.09
kirkuk	331	35.28	44.24
Khanaqin	202	34.21	45.23
Ramadi	48	33.27	43.19
Baghdad	32	33.18	44.24
Najaf	32	31.59	44.19
Nasiriya	5	31.01	46.14
Basra	3	30.31	47.47

The synoptic observation for the case study was provided by the Iraqi meteorological organization and seismology.

RESULTS AND DISCUSSION

The value of geopotential height decreased during the period (28-29 January 2013), indicating unsettled weather as shown in Table 2.

Table 2. The value of Geopotential Height at 500 hPa during the period (26-29 January 2013).

Station	26/1/2013	27/1/2013	28/1/2013	29/1/2013
Mosul	5661	5643	5607	5500
kirkuk	5680	5671	5635	5512
Khanaqin	5694	5696	5653	5518
Ramadi	5706	5700	5652	5540
Baghdad	5708	5710	5660	5536
Najaf	5727	5735	5683	5557
Nasiriya	5740	5752	5709	5558
Basra	5753	5763	5729	5571

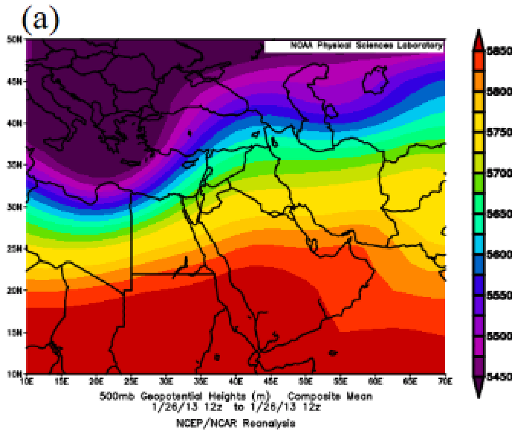
ISSN: 1814-635X (print), ISSN:2521-3520 (online) Volume 33, Issue 4, 2022 DOI: http://doi.org/10.23851/mjs.v33i4.1161

In this table, on 26 January 2013, the lowest value of geopotential height at 500 hPa was in the Mosul station (5661), while the highest value of geopotential height was in the Basra station (5753). The next day, the behavior of geopotential height was not consistent, with the northern region (Mosul, Kirkuk) experiencing a drop in geopotential height compared to the previous day, at Mosul station, the geopotential height dropped by around (18m) and Kirkuk station the geopotential height dropped by around (9m).In the middle region, The geopotential height dropped by (6m) at Ramadi station, while it increased at Baghdad and Khanaqin stations, where the increase in the geopotential height at Baghdad and Khanaqin stations was about (2m). In the southern region. There was an increase in the value of geopotential height, where the increase in the geopotential height was (8m) in Najaf, (12m) at Nasiriya, and (10m) at Basra.
On 28 January 2013, there was a noticeable decline in the value of geopotential height at 500hpa across Iraq, with a decrease of about (36m) in Mosul and Kirkuk stations, and a decrease in the middle area fluctuating between (43-50m) and a decrease in the southern region fluctuated between (34-52m). The geopotential height value decreased sharply on 29 January 2013, when a trough positioned over Iraq and was associated with cold advection. The lowest decrease was in the northern region, with the decrease at Mosul station (107m), and the highest decrease in the southern region, with the decrease at Basra station (158m).

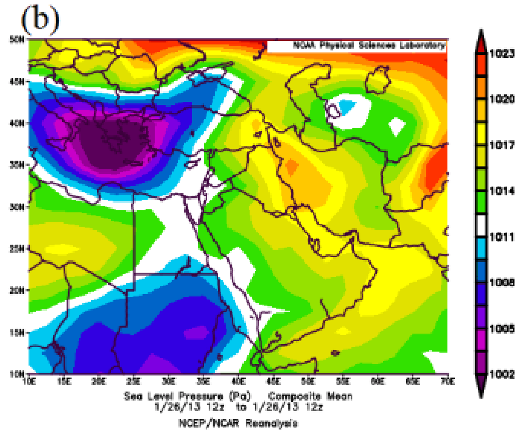
Synoptic Analysis (26-29 January 2013)

During 26-29 January 2013, the weather over Iraq was characterized by a case of instability where the geopotential height at 500 hPa map clearly indicates a trough at the eastern Mediterranean associated with the low-pressure system at the surface.
On 26 January 2013, the 500 hPa geopotential map illustrates a trough extended from Europe towards the Mediterranean as shown in (Figure 1a), this trough is associated with cold advection and cyclonic flow. On the surface, the sea level pressure map shows a low-pressure system over the Mediterranean as known Mediterranean low pressure which it is a form of mid-latitude low pressure and it is associated with an upper-level trough, this low-pressure system caused heavy rainfall events on the Mediterranean region and western turkey, another low pressure in the lower latitude over Sudan as known Sudanese low pressure, while there is a relatively high-pressure system over Iraq as illustrated in (Figure 1b), the wind in general was southeasterly (Figure 1c), the relative humidity fluctuated between 20%to 50% in the middle and southern parts of Iraq while in the northern parts of Iraq RH was more than 60% (Figure 1d). The weather in Iraq was partly cloudy to cloudy (see Figure 2).

(a)



(b)



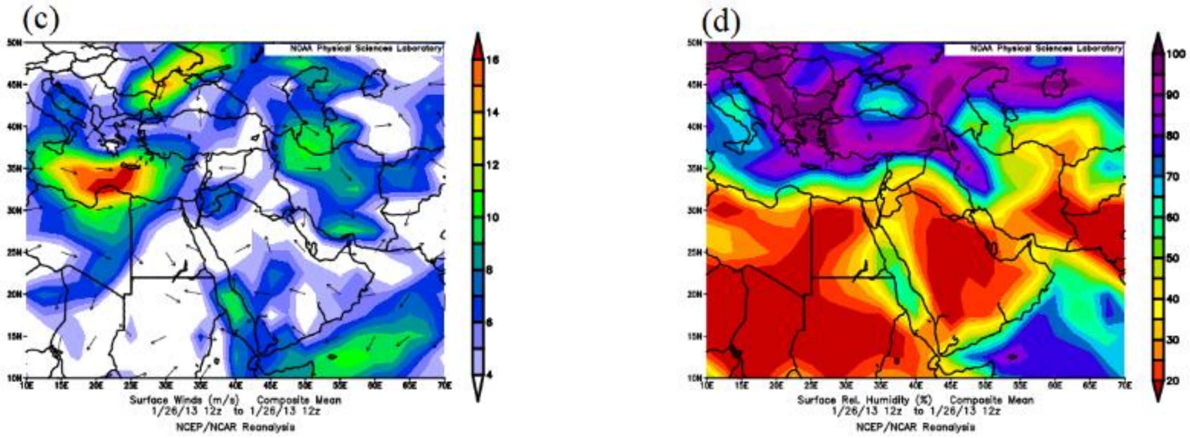


Figure 1. The synoptic maps for 26 January 2013, where (a) 500 hPa geopotential height (m), (b) sea level pressure (mb), (c) surface vector wind (m/s) and (d) surface relative humidity (%).

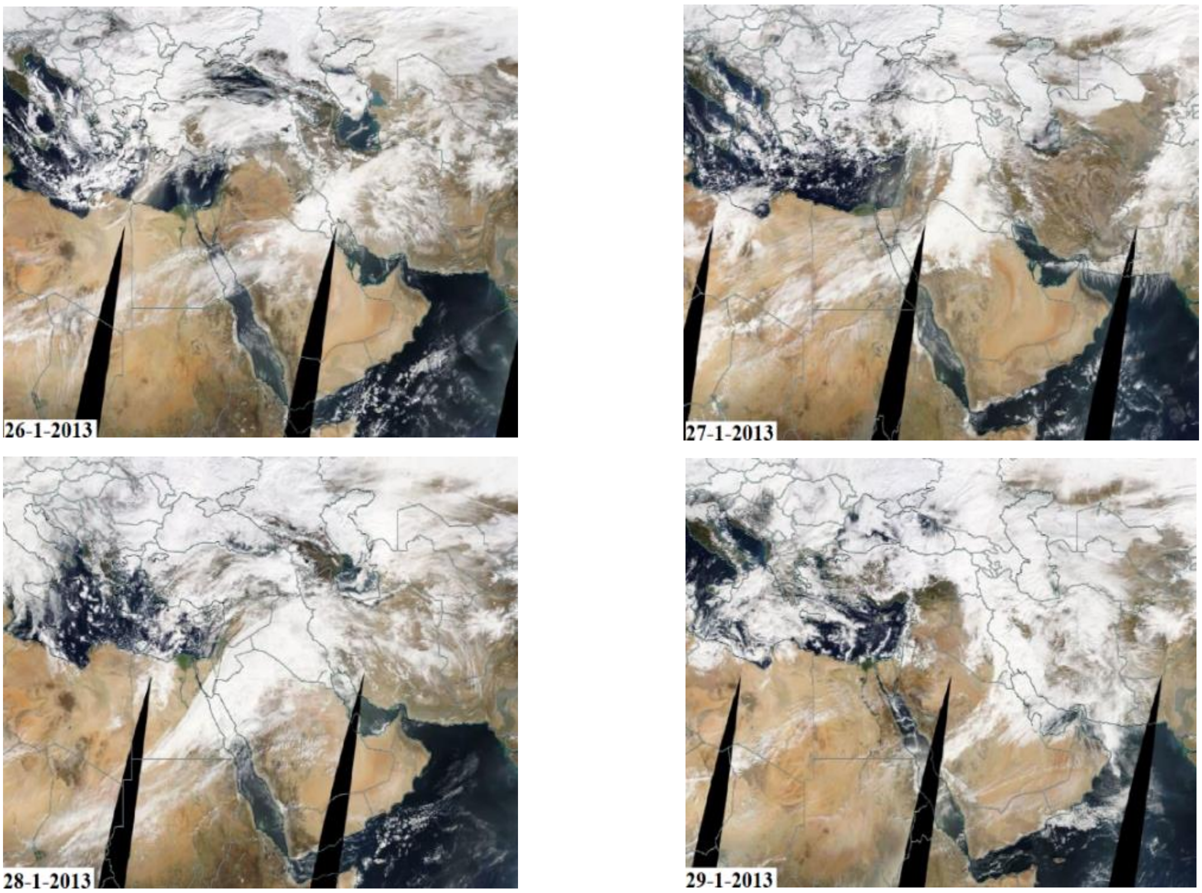


Figure 2. the satellite image for the middle east during the period (26-29 January 2013).

After 24 hours, the trough shifted to about 25N and positioned over eastern Mediterranean and northern Iraq while there is a relatively high value of geopotential height over southern Iraq and Arabian Peninsula as shown in (Figure 3a). The Mediterranean low pressure moved eastward to cover turkey Syria and northern Iraq, meanwhile the Sudanese low-pressure strengthen and propagated northward to about 20N as illustrated in (Figure 3b), the wind was southeasterly (Figure 3c). The relative humidity exceeded 80% in the northern parts of Iraq, while the rest parts of Iraq fluctuated between (40%-70%) (Figure 3d).

A moderate amount of rain fell in northern parts of Iraq, the Mosul station reported (24.3mm), while the weather in the center and south Iraq was cloudy with scanty rain as shown in (Figure 5b).

The trough deepens and shifted south-eastward on 28 January, positioning over the eastern Mediterranean and north red sea as shown in

ISSN: 1814-635X (print), ISSN:2521-3520 (online) Volume 33, Issue 4, 2022 DOI: http://doi.org/10.23851/mjs.v33i4.1161

(Figure 4a), the value of geopotential height at 500hpa decreased over Iraq as compared to the previous day as shown in Table 2. The propagation of the trough to the lower latitudes strengthens the Sudanese low pressure, which transforms into dynamic low pressure and spreads to higher latitudes as shown in (Figure 4b). When the Sudanese low pressure propagates northward and eastward and is accompanied by a trough from mid-latitudes causes heavy rainfall events in the Middle Eastern countries as known tropical extratropical interaction. In addition, the divergence at the upper-level trough enhances convergence at the surface, leading to ascending motion. The upward motion caused the strengthening of low pressure at the surface, while the southeasterly winds (Figure 4c) provided moist and warm air toward the region. The relative humidity increased as compared to the previous day (Figure 4d), the presence of a cold trough at the upper level and warm and moist air at the surface, provide the appropriate condition for instability, the atmosphere becomes highly unstable, heavy rain fell on parts of Iraq (Figure 5).

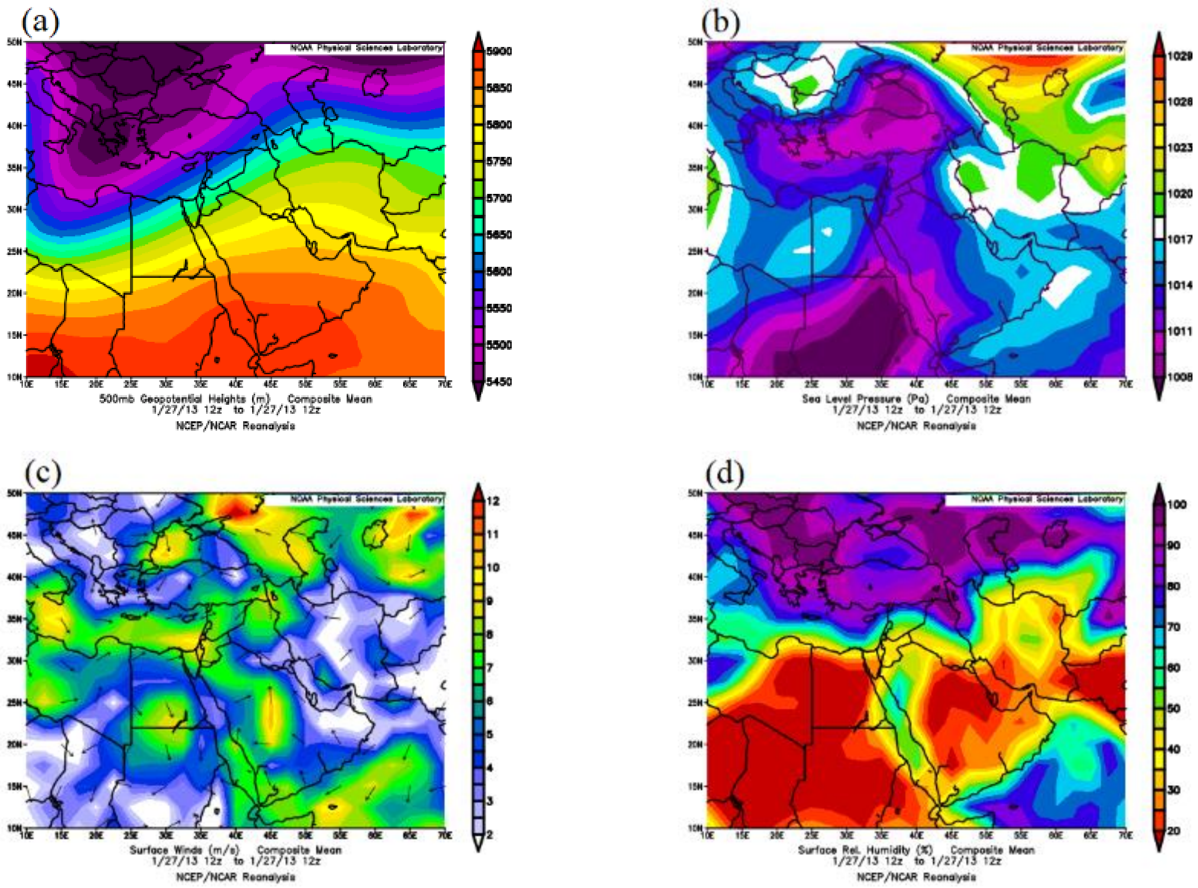


Figure 3. The synoptic maps for 27 January 2013, where (a) 500 hPa geopotential height (m), (b) sea level pressure (mb), (c) surface vector wind (m/s) and (d) surface relative humidity (%).

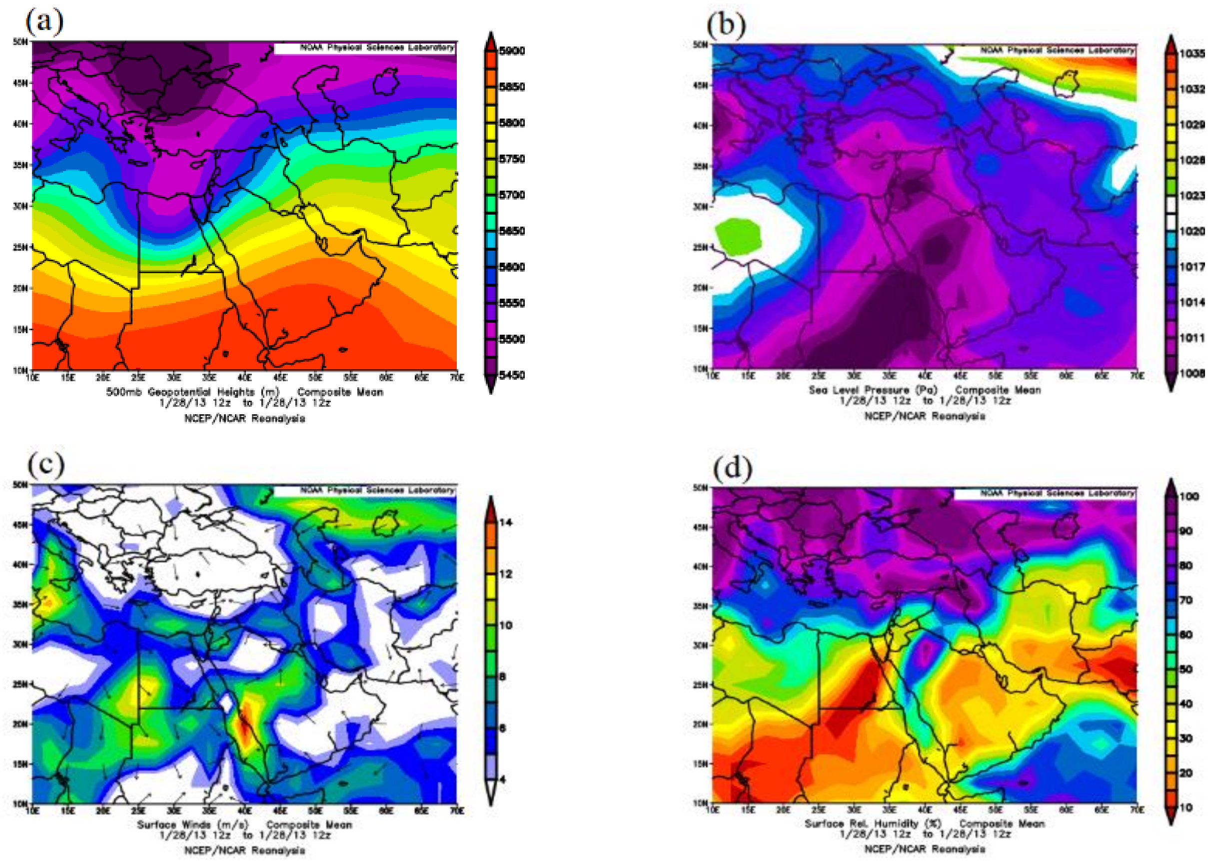


Figure 4. The synoptic maps for 28 January 2013, where (a) 500 hPa geopotential height (m), (b) sea level pressure (mb), (c) surface vector wind (m/s) and (d) surface relative humidity (%).

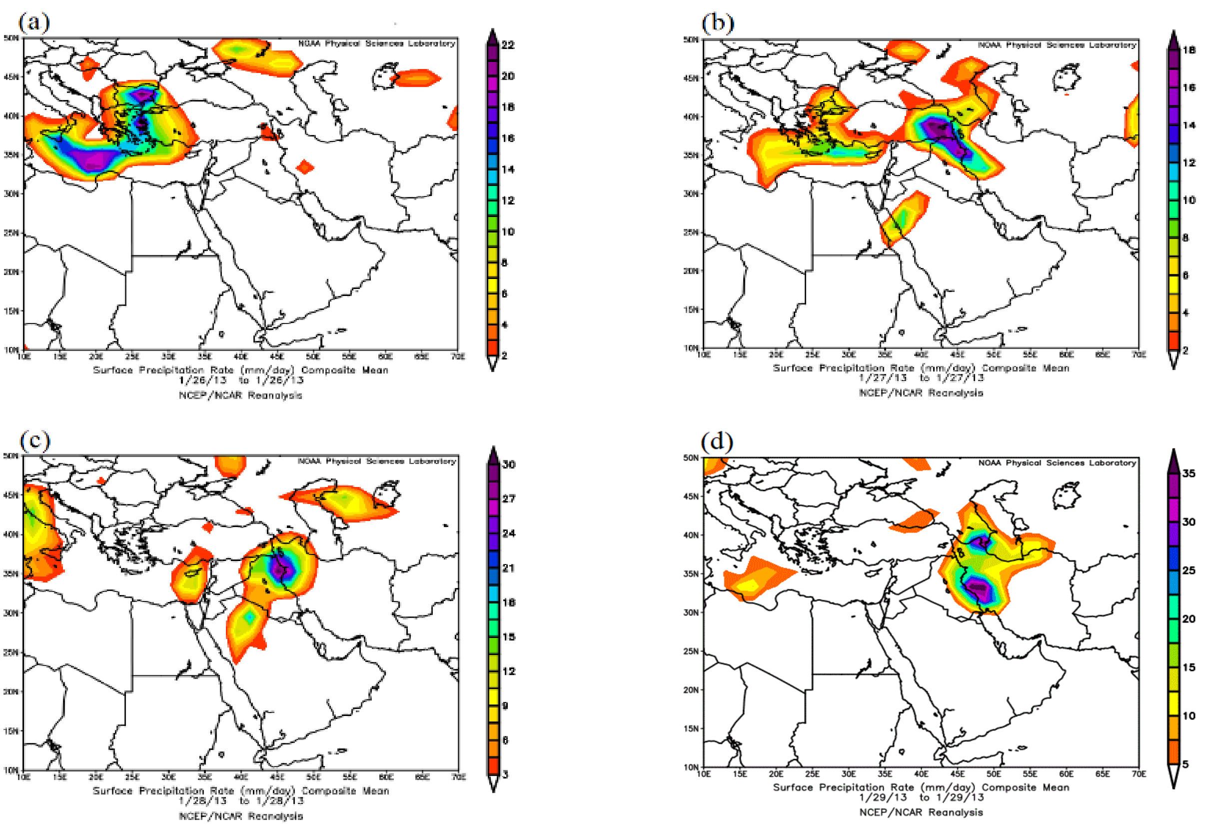


Figure 5. The rainfall amount (mm) during the period (26-29 January 2013).

According to Iraqi meteorological organization, the largest amount of rainfall reported in the Kirkuk station on 28 January was (72.2mm), whereas the amount of rainfall reported in the

ISSN: 1814-635X (print), ISSN:2521-3520 (online) Volume 33, Issue 4, 2022 DOI: http://doi.org/10.23851/mjs.v33i4.1161

Baghdad station was (47.3mm) and Mosul station (46.8mm), while the southern parts of Iraq reported the little to moderate amount of rain, where Najaf station reported (24.1mm) and Nassiriya station reported (3mm).

On 29 January, the trough positioned over Iraq as shown in (Figure 6a), the instability affected the eastern parts of Iraq, the low pressure centered over turkey, north and eastern parts of Iraq, and over Iran (Figure 6b), while the Sudanese low pressure dissipates, the wind turned to northwesterly (Figure 6c). The high relative humidity in the eastern parts of Iraq reached over 80% (Figure 6d). Heavy rain fell in eastern parts of Iraq (Figure 5d), with torrential downpours at the Iraqi-Iranian border, while the weather in the west of Iraq became clear to partly cloudy.

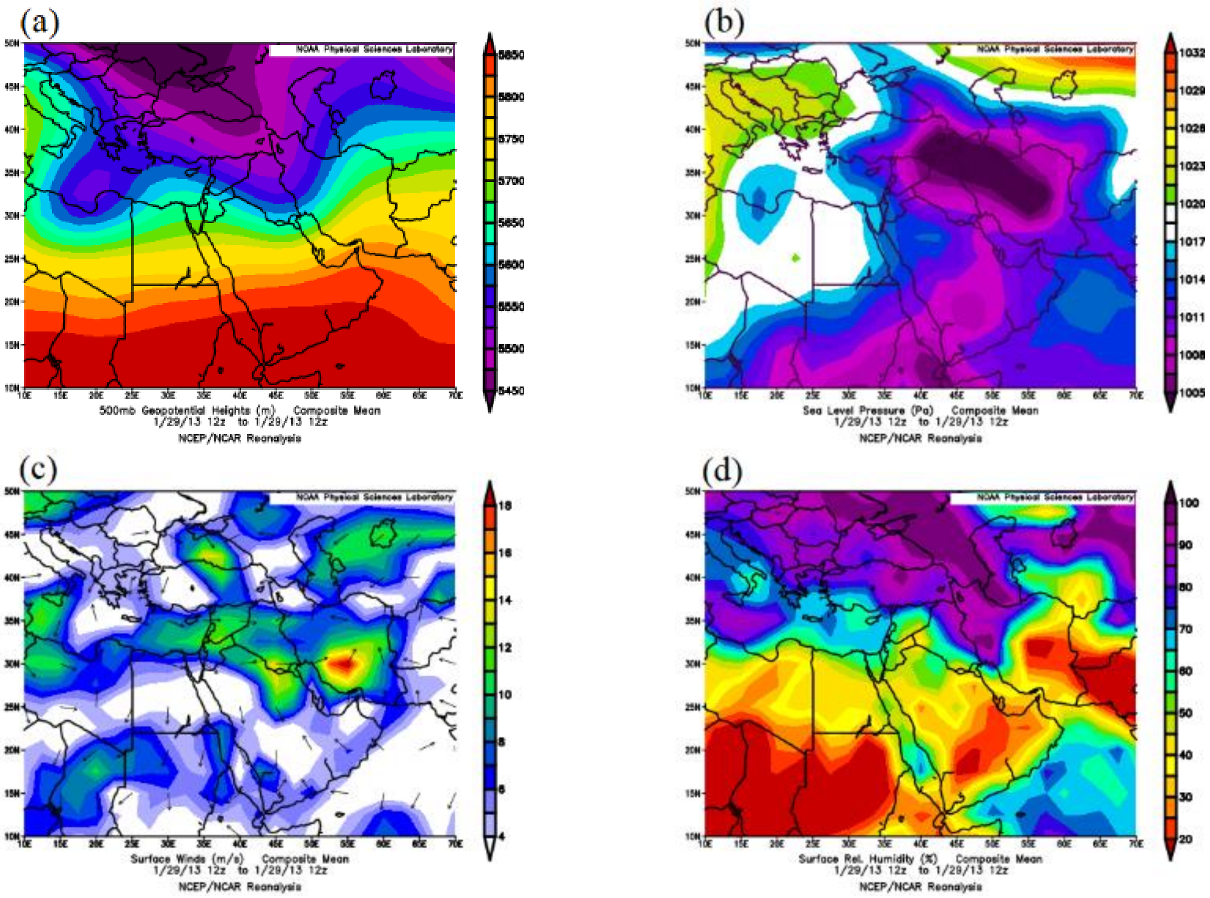


Figure 6. The synoptic maps for 29 January 2013, where (a) 500 hPa geopotential height (m), (b) sea level pressure (mb), (c) surface vector wind (m/s) and (d) surface relative humidity (%).

CONCLUSIONS

The geopotential height at 500 hPa is a key factor in determining the weather and climate conditions around the world. On (26-29 January 2013), a case of instability affected Iraq, where heavy rainfall hit parts of Iraq. During this period, the synoptic map at 500 hPa showed a trough stretched from Europe to the Mediterranean region and caused unsettled weather, when the trough prpogated southward, it enhances the Sudanese low pressure to spread north- eastward causing heavy rainfall events. The advection of humid and warm air from lower latitudes when accompanied by upper level trough provide a suitable condition for a baroclinic instability.

The value of geopotential height at 500 hPa decreased over Iraq as an indicator of active weather. The decrease in the value of geopotential height is sign of turbulent weather when compared to surrounding regions.

Disclosure and conflict of interest: The authors declare that they have no conflicts of interest.

REFERENCES

[1] O. M. A. M. Agha and N. Şarlak, "Spatial and temporal patterns of climate variables in Iraq," Arab. J. Geosci., vol. 9, no. 4, 2016. https://doi.org/10.1007/s12517-016-2324-y

[2] A. A. Attiya and B. G. Jones, "Climatology of Iraqi dust events during 1980-2015," SN Appl. Sci., vol. 2, no. 5, May 2020. https://doi.org/10.1007/s42452-020-2669-4

[3] N. Al-Ansari, A. A. Ali, and S. Knutsson, "Present Conditions and Future Challenges of Water Resources Problems in Iraq," J. Water Resour. Prot., vol. 06, no. 12, pp. 1066-1098, 2014. https://doi.org/10.4236/jwarp.2014.612102

[4] S. A. Salman, S. Shahid, T. Ismail, K. Ahmed, E. S. Chung, and X. J. Wang, "Characteristics of Annual and Seasonal Trends of Rainfall and Temperature in Iraq," Asia-Pacific J. Atmos. Sci., vol. 55, no. 3, pp. 429-438, 2019. https://doi.org/10.1007/s13143-018-0073-4

[5] A. S. Hassan, K. N. Zeki, and N. S. Salih, "Determination the quantity of extreme rainfall and calculation of the climatology mean for Baghdad City," Iraqi J. Sci., vol. 59, no. 1 B, pp. 447-455, 2018. https://doi.org/10.24996/ijs.2018.59.1B.25

[6] A. R. Al-Nassar and H. Kadhim, "Mapping Flash Floods in Iraq by Using GIS," Environ. Sci. Proc., vol. 8, no. 1, p. 39, Jul. 2021. https://doi.org/10.3390/ecas2021-10696

[7] A. Hochman, D. Rostkier-Edelstein, P. Kunin, and J. G. Pinto, "Changes in the characteristics of 'wet' and 'dry' Red Sea Trough over the Eastern Mediterranean in CMIP5 climate projections," Theoretical and Applied Climatology, vol.143, no. 01, pp. 781-794, 2021. https://doi.org/10.1007/s00704-020-03449-0

[8] H. Khozeymehnezhad and M. Nazeri Tahroudi, "Annual and seasonal distribution pattern of rainfall in Iran and neighboring regions," Arab. J. Geosci., vol. 12, no. 8, 2019. https://doi.org/10.1007/s12517-019-4442-9

[9] K. M. R. Hunt and A. Menon, "The 2018 Kerala floods: a climate change perspective," Clim. Dyn., vol. 54, no. 3-4, pp. 2433-2446, Feb. 2020. https://doi.org/10.1007/s00382-020-05123-7

[10] Y. Y. Hafez and M. Almazroui, "Recent Study of Anomaly of Global Annual Geopotential Height and Global Warming," Atmos. Clim. Sci., vol. 04, no. 03, pp. 347-357, 2014. https://doi.org/10.4236/acs.2014.43035

[11] D. Q. Hmood Abd and A. K. Abdul kareem, "Synoptic Analysis for the Daily Rains of the City of Baghdad," Al-Mustansiriyah J. Sci., vol. 32, no. 2, p. 51-57,2021. https://doi.org/10.23851/mjs.v32i2.983

[12] A. G. Mutar, A. Khtan, and L. E. George, "Synoptic Characteristics of Torrential Rains in Southwest and Southeast Iraq: A Case Study," Al-Mustansiriyah J. Sci., vol. 32, no. 3, p. 1-7,2021. https://doi.org/10.23851/mjs.v32i3.957

[13] A. Raheem Al-Nassar, J. L. Pelegrí, P. Sangrà, and M. Alarcon, "Cut-off low systems over Iraq: contribution to annual precipitation and synoptic analysis of extreme events."vol. 40, no. 2, p. 908-926,2021. https://doi.org/10.1002/joc.6247

[14] S. Issa and J. Kadhum, "Dynamical Analysis of Severe Rain Events over Iraq," Al-Mustansiriyah J. Sci., vol. 30, no. 1, pp. 15-22, 2019. https://doi.org/10.23851/mjs.v30i1.586

[15] A. M. Al-Lami, Y. K. Al-Timimi, and H. K. A. Al-Shamarti, "Spatiotemporal analysis of some extreme rainfall indices over Iraq (1981-2017)," Sci. Rev. Eng. Environ. Sci., vol. 30, no. 2, pp. 221-235, 2021. https://doi.org/10.22630/PNIKS.2021.30.2.19

[16] A. Al-Salihi, A. Allami, and Y. Kadhim, "Spatiotemporal Analysis of Annual and Seasonal Rainfall Trends for Iraq," Al-Mustansiriyah J. Sci., vol. 25, no. 1, pp. 153-168, 2014.

[17] S. A. Khidher and P. Pilesjö, "The effect of the North Atlantic Oscillation on the Iraqi climate 1982-2000," Theor. Appl. Climatol., vol. 122, no. 3-4, pp. 771-782, 2015. https://doi.org/10.1007/s00704-014-1327-4

[18] K. M. R. Hunt, A. G. Turner, and R. K. H. Schiemann, "How Interactions between Tropical Depressions and Western Disturbances Affect Heavy Precipitation in South Asia,"vol. 149, no. 6, pp. 1801-1825, 2021. https://doi.org/10.1175/MWR-D-20-0373.1

[19] M. Almazroui, S. Kamil, K. Ammar, K. Keay, and A. O. Alamoudi, "Climatology of the 500-hPa mediterranean storms associated with Saudi Arabia wet season precipitation," Clim. Dyn., vol. 47, no. 9, pp.3029-3042,2016. https://doi.org/10.1007/s00382-016-3011-0

[20] L. Deng, M. F. Mccabe, G. Stenchikov, J. P. Evans, and P. A. Kucera, "Simulation of flash-flood-producing storm events in Saudi Arabia using the weather research and forecasting model," J. Hydrometeorol., vol. 16, no. 2, pp. 615-630, 2015. https://doi.org/10.1175/JHM-D-14-0126.1

[21] Y. Ai and W. Qian, "Anomaly-based synoptic analysis on the Heavy Rain Event of July 2018 in Japan," Nat. Hazards, vol. 101, no. 3, pp. 651-668, 2020. https://doi.org/10.1007/s11069-020-03888-y

[22] "Daily Climate Composites: NOAA Physical Sciences Laboratory." https://psl.noaa.gov/data/composites/day/ (accessed Jan. 27, 2022).

[23] "ECMWF ERA Interim, Daily." https://apps.ecmwf.int/datasets/data/interim-full-daily/levtype=sfc/ (accessed Mar. 21, 2022).

[24] "WorldviewSnapshots." https://wvs.earthdata.nasa.gov/ (accessed Mar. 21, 2022).

How to Cite

M. A. R. Jabbar and A. S. . Hassan, "Evaluation of Geopotential Height at 500 hpa with Rainfall Events: A Case Study of Iraq", *Al-Mustansiriyah Journal of Science*, vol. 33, no. 4, pp. 1–8, Dec. 2022.