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Original article

Exploring the impact of weather patterns on exceptional flooding events in the Nekor watershed, NE Morocco

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ABSTRACT

This study investigates the recurring floods within the Nekor Basin of NE Morocco, a phenomenon dating back to 1944. A multitude of factors has contributed to these recurrent floods, which profoundly affect the northern region encompassing the Nekor Plain. The research primarily investigates the influence of specific weather conditions on the surge of water levels in "Wadi Nekor" and the ensuing consequences when the valley veers from its primary course. The research findings strongly indicate that a significant portion of these flood events can be attributed to "Cut-Off Low" (COL) and atmospheric rivers (ARs), frequently aligning with mean sea level pressure (MSLP) systems located over, or in proximity to, the Moroccan region. This study employs a systematic classification and arrangement methodology for both upper and lower atmospheric levels in analyzing pertinent cases.

KEY WORDS: Nekor watershed, exceptional flooding, temperature, mean sea level pressure, (MBAK) Dam

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1. Introduction

Environmental disasters related to water resources have become increasingly important subjects of study, particularly floods, which are considered both recurrent and destructive (Samanta et al., 2018; Nsangou et al., 2022). They represent 48.2% of disasters recorded in 2013 worldwide, resulting in nearly 32 million victims, or 33.2% of the total number of people affected by natural disasters (CRED, 2014). Studies that have addressed the issue of floods in river basins have focused on addressing the causes and spatial consequences of these floods. Although floods are primarily caused by natural factors, certain human interventions can exacerbate their severity (Bronstert, 2003; Saint-Laurent, 2007; Di Baldassarre et al., 2013; Youssef et el., 2016; Viero et al., 2019), especially since the Nakor Basin has witnessed significant urban expansion in recent decades.

Precipitation patterns play a pivotal role in shaping surface runoff characteristics and are recognized as one of the foremost factors contributing to flood events (Fiorentino et al., 2007). The distribution of rainfall in the Nekor Basin varies significantly within its different regions, and displaying notable fluctuations in these patterns (Zemzami & Haida, 2023). Many studies indicate notable recent decreases in precipitation in the Mediterranean region (Esteban-Parra et al., 1998;

SUMNER ET AL., 2003). This trend is consistent with assessments made in the eastern regions of Morocco (SNAIBI ET AL., 2021) and the eastern Mediterranean regions (KELLEY ET AL., 2012).

Due to its vulnerability to the impacts of the Mediterranean Sea, the Nekor watershed is considered a climate-sensitive area. Projections anticipate an increase in heavy rainfall in its surrounding areas in a warmer world, driven by the strengthening hydrological cycle (ALLEN & INGRAM, 2002; GIORGI ET AL., 2019; ZITTIS ET AL., 2021), as well as mounting urbanization pressures (LARABI ET AL., 2020).

In the southern regions, positioned at an elevation of 2009 meters above sea level, average annual rainfall exceeds 500 mm, while northern areas record precipitation levels below 400 mm. In the northern part of the basin (at an elevation of 8.5 meters above sea level), rainfall levels fall below this aforementioned average at multiple monitoring stations.

Several models have been adopted for the precise estimation of floods by researchers and government agencies (TALEI ET AL., 2010; KISI ET AL., 2012; SAMANTA ET AL., 2018). However, there is currently a limited body of research addressing flooding in the Nekor Basin. This study seeks to elucidate the temporal and spatial variations influenced by rainfall within the Nekor Basin. We are conducting a comprehensive time series analysis spanning three decades to achieve this aim.

To gain a comprehensive understanding of the impact of upwelling in the Nekor Basin, we have examined specific instances of exceptional flooding events within the basin. This analysis involved correlating the daily hydrological data recorded from 1994 to 2008 with corresponding daily precipitation records. Furthermore, to deepen our understanding of this issue, we have conducted an in-depth analysis of the atmospheric mechanisms contributing to the formation of weather patterns responsible for these floods (PATTISON & LANE, 2012; WELBY & QUINN, 2013; ROBERTSON ET AL., 2015; GILABERT & LLASAT, 2018; TOLIKA & SKOULIKARIS, 2023). This has involved examining and analyzing the atmospheric conditions at the 500 hPa altitude level and sea level pressure (0).

The main aim of the study was to inventory and analyze flood cases and also to propose practical measures that can contribute to mitigating the impact of floods in the Nekor Basin. This is especially crucial in light of the substantial urban expansion occurring in the region.

2. Materials and methods

2.1. Study area

Situated in the northeastern region of Morocco (Fig. 1), the Nekor watershed is located between 34°43.99′ to 35°8.02′ north latitude and 4°3.64′ to 3°38.58′ west longitude. It covers an area of 790 km^2 at the level of the (ABHL) dam. When considering the additional area of the surrounding plain, approximately 63 km^2, the total area expands to 841 km^2 (AMIL, 1992). This region exhibits characteristics specific to the Riffian domain (NIAZI ET AL., 2005). The overall slope index across the watershed is 20.7 m km-1 (ARREBEI ET AL., 2019). On the left bank, this index is higher than on the right bank (LAHLOU, 1990). This basin is positioned among the Moroccan Mediterranean interface basins and is notably influenced by the transient Mediterranean climate, with a tendency toward aridity (ARRAJI, 2015).

The elevations in the Nekor Basin exhibit a gradual variation from South to North. At the Nekor plain, the elevation is at sea level, reaching 0 meters, while it increases to 120 meters at the (MBAK) dam. Elevations along the watershed divide mostly surpass 1200 meters, with the highest points measured at Mount Marzouk in the south (1735 m) and Mount Chakran on the western bank of the basin (1830 m). The highest elevation is registered at Mount Azro Akachar in the southernmost region, reaching 2009 meters. This diverse topography significantly contributes to enhancing the flow of water from south to north, aligning with the main course of the 40 kilometre-long wadi Nekor, there by influencing surface water.

2.2. Data

The Nekor Basin hasseven measuring stations. Among these stations, only the Al Hoceima Airport station provides measurements for most climatic elements, while the remaining stations primarily provide data on precipitation. Additionally, certain stations also gauge river discharge, with the Tamlahat station being one notable example. We procured this data from diverse sources, with a predominant portion originating from the Loukkos Hydraulic Basin Agency (ABHL). Data pertaining to the Al Hoceima Airport station was acquired through the National Meteorological Office of Morocco (DMN). Other crucial datasets were obtained from the Regional Directorate of Agriculture in Imzouren.

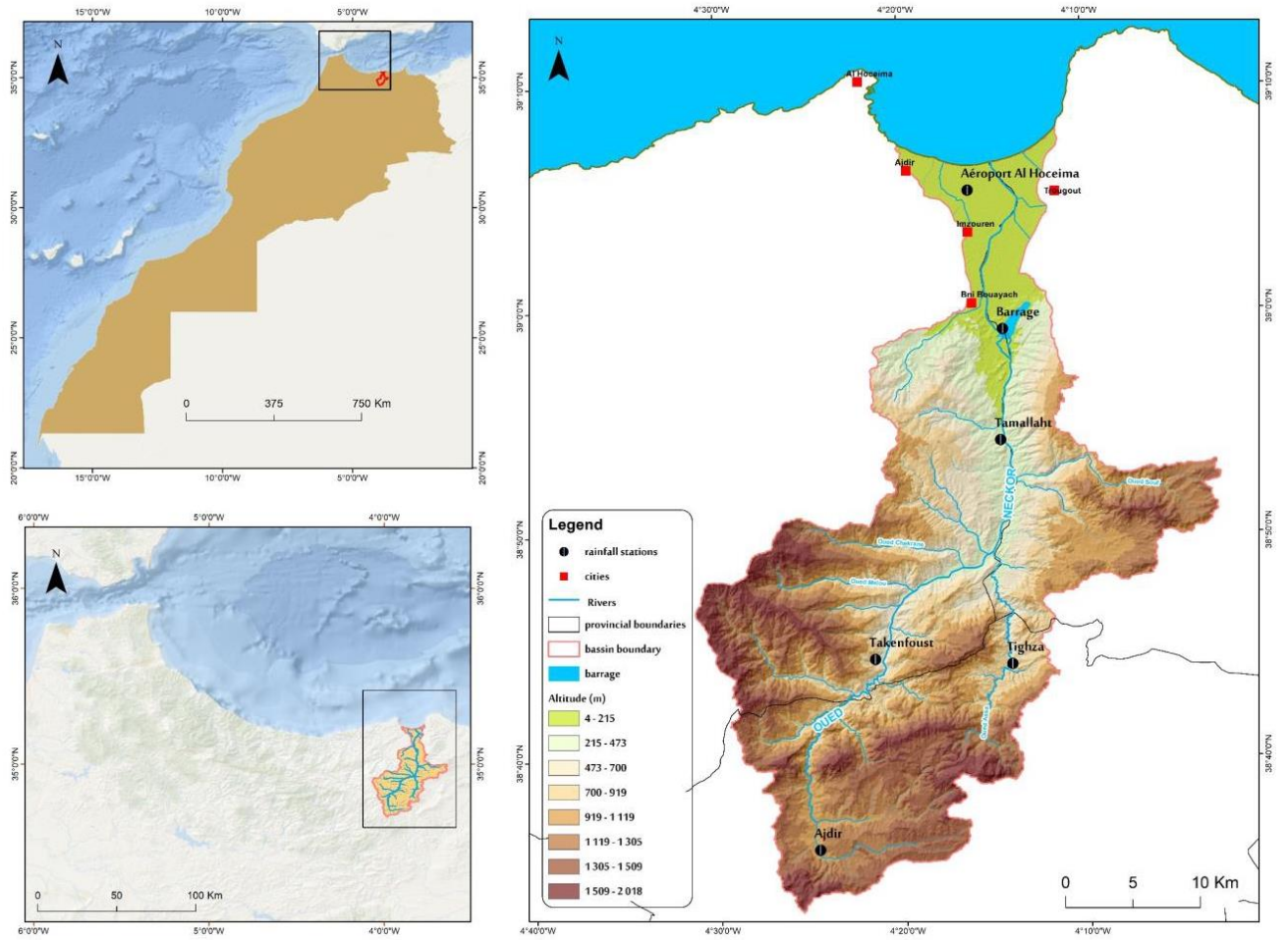


Fig. 1. Location of the study area (Source: author's achievement, 2023)

Comprehensive synoptic weather charts are vital documents that facilitate the examination of weather events within specific domains. Numerous scientific investigations have employed these charts to categorize weather occurrences across various fields and to establish associations with distinct climatic factors, particularly concerning rainfall variability (ITURRIOZ ET AL., 2007; CASADO ET AL., 2010; LEMUS-CANOVAS ET AL., 2019). Additionally, endeavours have been undertaken to link these classifications with extreme temperatures, which serve as indicators of a shifting climate (KYSELÝ, 2008; JONES ET AL., 2009). In this article, our aim was to establish a connection between the documented floods in the Nekor Basin spanning from 1994 to 2008 and the corresponding daily precipitation. Subsequently, we elucidate these phenomena by investigating the atmospheric structures that gave rise to these events.

We scrutinized weather maps generated by various global models, yielding a substantial repository of weather data for evaluating these maps at both the lower (MSLP) and upper (500 hPa) levels. For Geopotential map data, we utilized the US weather service's Global Forecast System (GFS) and the European Centre for Medium-Range Weather Forecasts (ECMWF) global models. Synoptic maps were obtained from the Deutscher Wetterdienst (DWD). The data was acquired through the [www.wetterzentrale.de] website, which provides weather maps and data for various regions starting from the year 1979.

2.3. Methods

To gain a comprehensive understanding of rainfall patterns in the Nekor Basin, it was imperative to conduct a long-term study spanning more than 30 years, and encompassing various meteorological stations. This research employed a methodological approach that involved the systematic analysis of major rainy periods documented in the Nekor Basin between 1994 and 2020. This period was selected due to its alignment with the majority of flood events observed within the basin.

The analysis leveraged quantiles derived from local surface gauge precipitation data to construct comprehensive composite maps, specifically conditional mean fields. These maps encompass a wide array of meteorological parameters, including vertically integrated moisture flux, low-level wind patterns, sea-level pressure, and 500hPa height, covering the Atlantic and European domains (RUDARI, 2005). This approach ensures a robust and in-depth exploration of the rainfall dynamics in the Nekor Basin.

Rainfall in the Nekor Basin displays marked temporal variability, often falling below the long-term average for most seasons and across various monitoring stations (Fig. 2). This variability is influenced by a mix of static and dynamic factors that shape the region's climatic conditions.

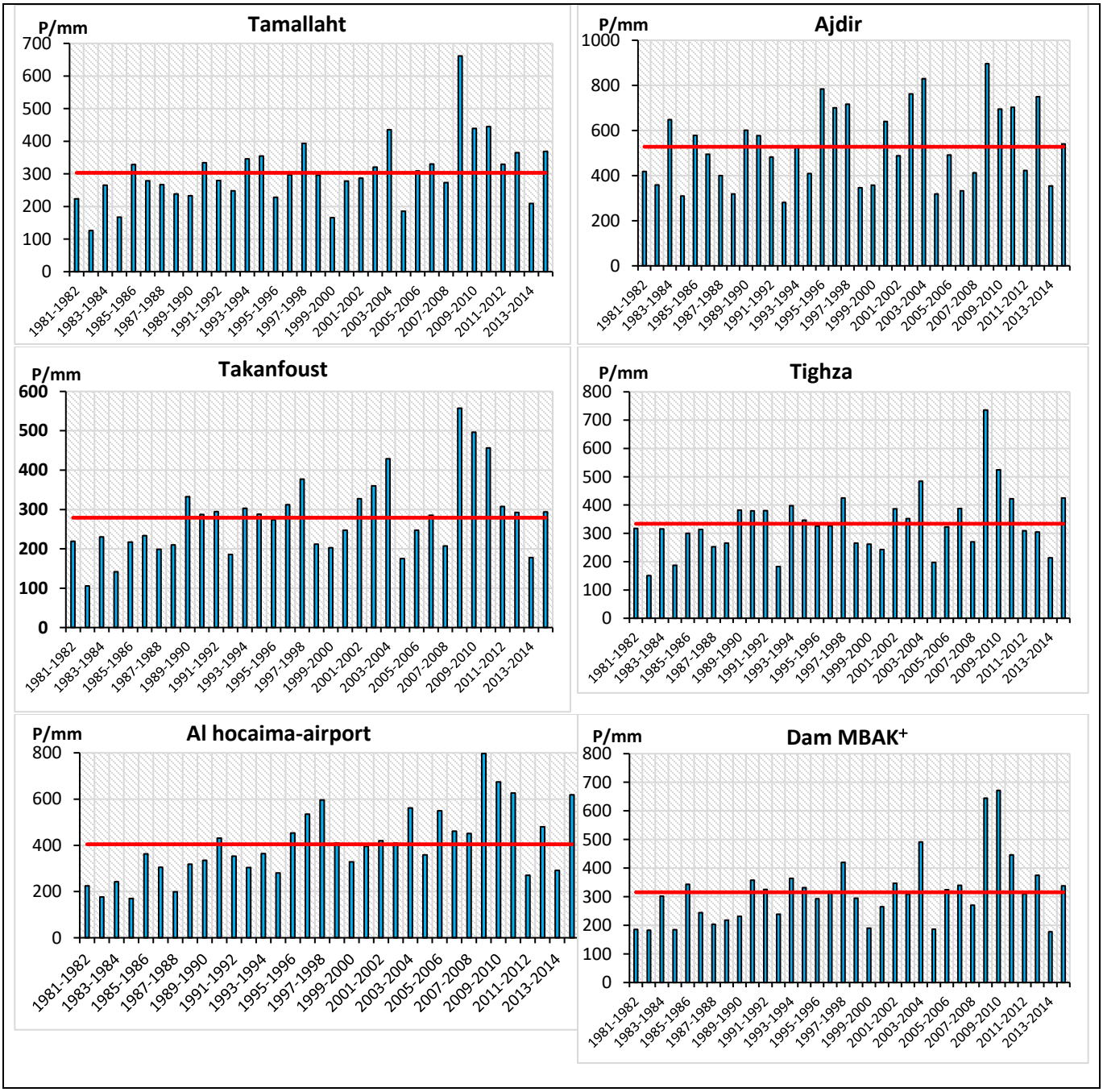


Fig. 2. Annual rainfall variations in the Nekor Basin from 1981/1982 to 2014/2015 (+ Dam Mohamed ben Abdelkrim Elkhatabi)

For example, the Ajdir station, positioned at a higher elevation within the basin, experiences substantial rainfall levels compared to other stations. This can be attributed to its location in a semi-humid zone, benefiting from an elevation of 2009 meters. However, this is not a universal rule, as the Tamellaht station, located at an elevation of 520 meters in the central part of the basin, does not receive significant precipitation. Conversely, the Al hoceima airport station, despite its relatively low elevation of only 12.5 meters, benefits from its proximity to the sea, enabling it to tap into the moisture-laden influences of maritime conditions (Fig. 2). Over the study period from 1994 to 2008, approximately seven cases were observed in which exceptional rainfall events occurred. These events resulted in an increase in the water level of the Nekor valley, with some of them escalating into floods that impacted the southern plain. Basic statistics on the dataset are presented in Table 1.

Between 1994 and 2008, the Nekor Basin experienced significant repercussions from extreme rainfall events, as detailed in Table 1. The elevation of the water level in the valley and the subsequent filling of the (MBAK) Dam serve as clear indicators of this impact. It is crucial to acknowledge that the representation of rainfall in the basin cannot be accurately captured by relying solely on data from a single monitoring station. To comprehensively understand the dynamics, it is essential to incorporate data from stations situated at higher elevations. These higher-elevation stations provide vital insights into events that have downstream effects on the lower reaches of the basin. Consequently, in order to gain a comprehensive understanding of rainfall patterns and their implications, it is imperative to cross-verify rainfall measurements obtained from stations in the upper basin (CLARKE ET AL., 2011; HIERRO ET AL., 2015).

The cases examined in this study exhibit variations in the patterns of rainfall that triggered them. For instance, in November 2003 and the final third of October 2008, there were instances of prolonged rain over five consecutive days, with accumulated precipitation reaching 271.4 mm and 243.9 mm, respectively. In contrast, the case on October 9, 2008, was characterized by isolated, intense rainfall events. This phenomenon, characteristic of the Mediterranean climate (RIBAS ET AL., 2019), has been a prominent feature leading to rapid increases in the water level of the Nekor Valley. Notably, the latter case resulted in substantial material losses.

Table 1. The most important rainfall events in the Nekor Basin from 1994 to 2008

Days	Volumes	Flow rate [m^3/s]	Rain height [mm]	Precipitation accumulation [mm]
17/01/1994	17267	0.2	16.0	137.8
18/01/1994	3854767	44.615	99.5	
19/01/1994	5064492	58.617	22.3	
16/11/2003	1097077	1.657	13.3	222.3
17/11/2003	35465150	12.698	63.8	
18/11/2003	1605022	410.476	95.5	
19/11/2003	1905392	18.577	47.0	
20/11/2003	808782	22.053	2.7	
09/10/2008	1573105	18.207	59.2	59.2
22/10/2008	1288168	14.909	15.2	243.9
23/10/2008	5704701	66.027	12.2	
24/10/2008	19679253	227.769	36.7	
25/10/2008	13781223	159.505	57.7	
26/10/2008	2476954	28.668	113.8	
27/10/2008	3197957	37.013	2.1	
28/10/2008	1308013	15.139	6.2	

Understanding the floods in the basin during the selected study periods is of utmost importance. Therefore, it is crucial to choose a reliable method through which we can comprehend the workings of the atmospheric system, which produces weather events that can be considered exceptional over the past four decades, at least. It should be noted that studying the structure of the lower troposphere's atmospheric system would not be limited to specific cases alone. We have tracked each case from its beginning to its end by retrieving the corresponding archives for each individual case.

3. Results and discussion

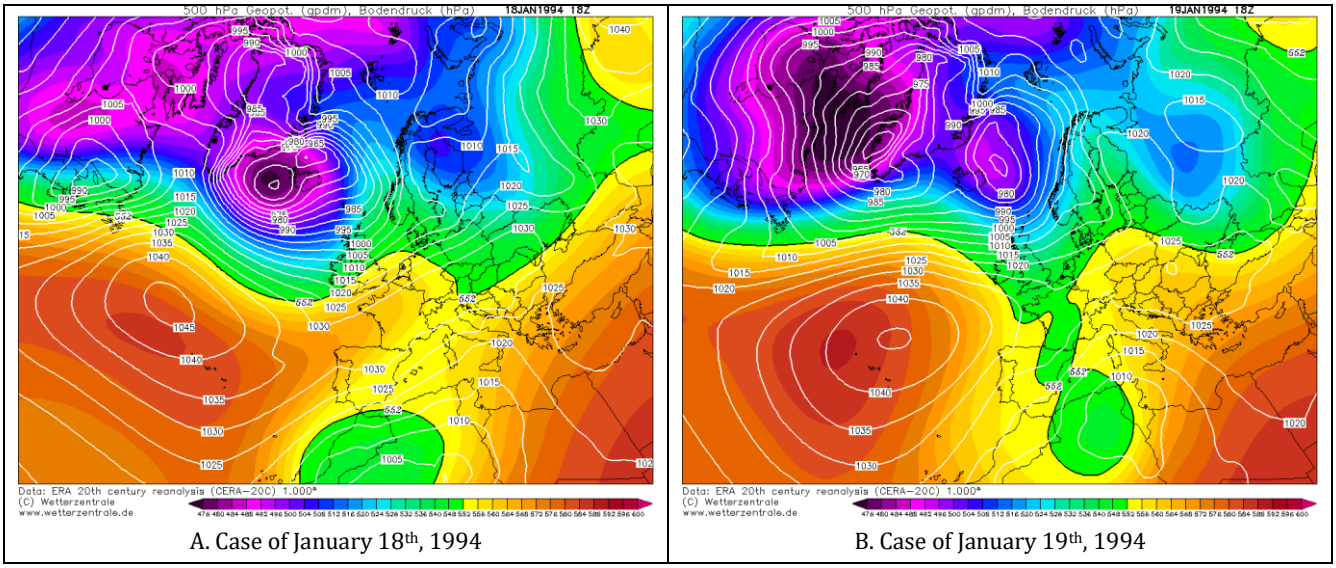
3.1. Case study: January 19th, 1994

January 19th, 1994, marked a significant event when the Mohamed Ben Abdelkrim Al Khattabi (MBAK) Dam experienced a substantial inflow of water, exceeding 5 M/m^3. On this day, the flow rate in the valley surged to 28 m^3 per second, accompanied by a recorded precipitation of approximately 22.3 mm. To gain a comprehensive understanding of the events of this day, it is crucial to revisit the sequence of occurrences leading up to it. Notably, this weather phenomenon commenced on January 16 and reached its zenith on January 18, with a precipitation level of approximately 100 mm. However, the most pronounced impact was witnessed on January 19th, which forms the centerpiece of our discussion.

Signs of an atmospheric system change became evident on January 15th, as the prevailing wind direction shifted from northwest to north at 500 hPa. This transition indicated a shift from the established atmospheric state to a descending state, which persisted until January 16th. This transition continued to evolve and exerted a significant influence on the weather, resulting in precipitation measuring 4.5 mm. Regarding sea-level pressure, the Moroccan region experienced a transitional situation, with pressure readings ranging between 1015 and 1020 hPa.

On January 17th, a broad valley took shape at a certain latitude, particularly impacting the Nekor Basin. This situation led to the dam station recording a rainfall amount of 16 mm. At sea level, the transitional conditions persisted.

On January 18th, a weather phenomenon known as a "Cut off Low" materialized over the northern part of Morocco, extending into the western region of Algeria (Fig. 3A). This development significantly impacted the northern regions of Morocco, with rainfall reaching an impressive 100 mm at the dam station on that day. The heavy rainfall had a remarkable impact on the flow of the (MBAK) Dam, surpassing 3.8 $M.m^3$ on that day. Furthermore, the valley's throughput surged to 44.6 m^3/s. The consequences of this situation were exceptional, prompting the implementation of precautionary measures to avert potential disasters. One such measure involved redirecting the excess water from the dam towards the sea.



A. Case of January 18th, 1994

B. Case of January 19th, 1994

Fig. 3. The atmospheric conditions leading to the examined weather type on January 19th, 1994

January 19th witnessed a remarkable shift in the weather system, as transitional indicators re-emerged, transitioning from a valley to a ridge pattern. This shift was driven by a northwesterly current transforming into a northerly one (Fig. 3B). Although the amount of precipitation decreased to 22.3 mm on this day, the dam received an influx of more than 5 M.m^3 of water. The valley's flow rate surged beyond 58 m^3/s. This remarkable increase can be attributed to the substantial precipitation observed in the southern regions of the basin on this particular day.

3.2. Case study: November 17th, 2003

The meteorological phenomenon persisted for a duration of 5 days within this timeframe, commencing on November 16 and concluding on the 20th. Over this period, it delivered an approximate total of 222 mm of precipitation at the measurement station located at the dam.

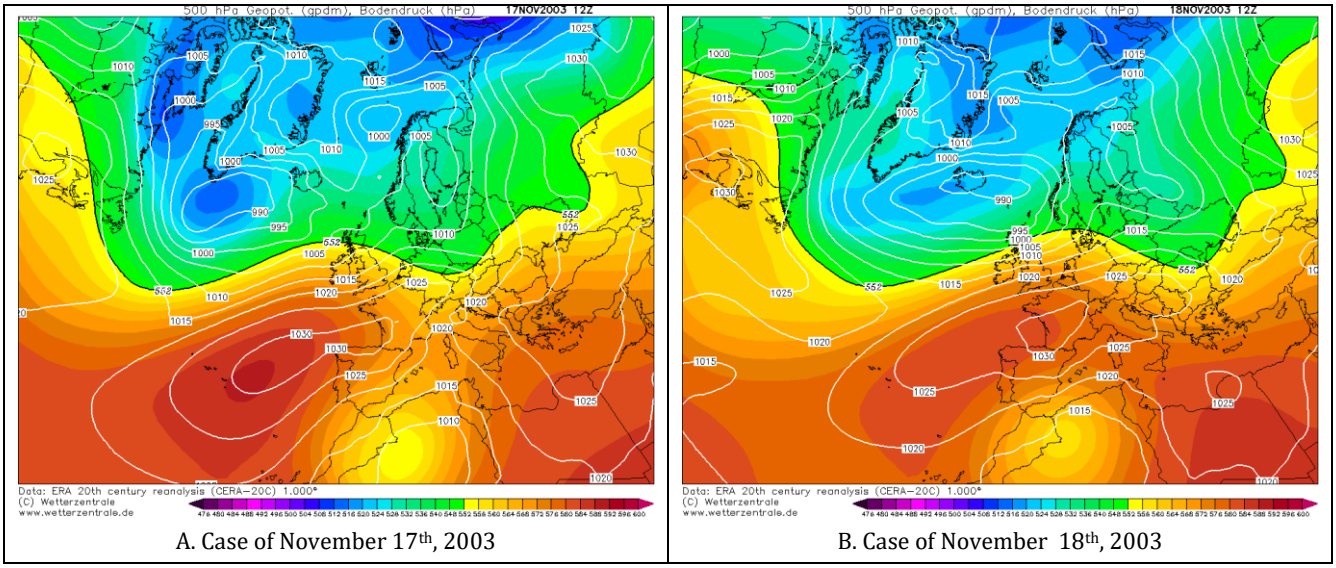
On the 17th, which holds relevance to this particular case, the (MBAK) Dam received an impressive 35,465,150 m^3 of water, while the flow rate of Wadi al-Nekor exceeded 12.6 m/s. Precipitation at the dam measured about 63.8 mm, whereas at the Ajdir station, it exceeded 102 mm, accounting for the rapid increase in water levels.

On November 18th, there was a notable escalation in precipitation at the dam station, reaching approximately 95.5 mm. Simultaneously, the flow rate of Wadi al-Nekor surged to 410.5 m/s.

The atmospheric configuration at 500 hPa that contributed to the genesis of this weather pattern was marked by the formation of a short valley, somewhat limited in latitude, which spanned across most of the northern regions of Morocco. Subsequently, this situation evolved into the development of a "Cut off Low," centered over Algeria on the following day, with our region situated on its western flank. This positioning indicated that northward airflow would dominate the atmospheric conditions and restore terrain stability in the upcoming days (Fig. 4A & B).

At sea level, on November 17th, a low-pressure system (below 1010 hPa) was centered over the Maghreb to the south, which contributed to the weather conditions. Simultaneously, over the Atlantic Ocean to the west of the region, a high-pressure system with a pressure value of 1030 hPa prevailed. Cumulus clouds blanketed the southern Mediterranean basin, extending from Tunisia in the east to Morocco in the west. This cloud cover indicates that the disturbances affecting the Nekor basin originated from tropical sources and were expected to evolve into a Mediterranean-like disturbance in the upcoming days.

In the days ahead, an anticyclone would dominate the southern region of Europe, creating a "blockade" for the Mediterranean disturbances. This resulted in the circulation of these disturbances in a counter-clockwise direction, sometimes persisting for up to five days. This weather pattern wasaccompanied by substantial rainfall, leading to the formation of torrents and, on numerous occasions, triggering floods.



A. Case of November 17th, 2003

B. Case of November 18th, 2003

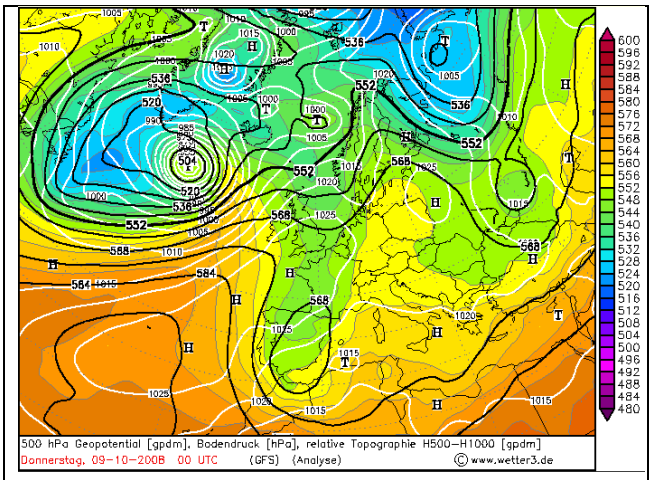
Fig. 4. The atmospheric situation producing the studied weather type on November 17th, 2003

3.3. Case study: October 2008

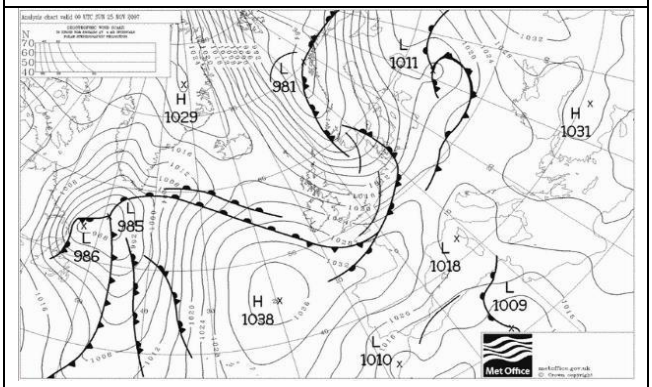
October 2008 witnessed two distinct rainy periods. The first occurred during the initial third of the month, with Al hoceima Airport station recording approximately 60 mm of precipitation. Subsequently, the weather stabilized through the second third of October. However, instability reemerged on October 21st and persisted for approximately a week. Rainfall gradually intensified, culminating on October 26th with a total of around 113 mm.

At the 500 hPa level, the prevailing weather conditions were marked by the presence of a broad, relatively underdeveloped ridge/valley configuration oriented latitudinally (Fig. 5A). This atmospheric setup facilitated a northeastward flow akin to a jet stream, driven by the convergence of isobaric lines. It is noteworthy that the movement of such valleys is a crucial process in generating significant moisture, especially when these valleys are deep and well-defined at a particular latitude. In the context of the Nekor basin, these conditions often translate to a consistently humid environment, influencing a large portion of the region.

The weather situation at sea level reveals the region's position within a high-pressure system centred over the Atlantic Ocean. To the north of the Atlantic Ocean, a low-pressure system induces disturbances that extend across the Atlantic, northern and southern Europe, eventually reaching Morocco. While this atmospheric pattern is not inherently indicative of turbulent weather conditions capable of generating substantial rainfall, a noteworthy phenomenon occurs in the extreme northeast of the country. Here, a massive cloud mass originating from the Sahara region (south of Algeria and southwest of Mauritania) becomes apparent. Referring back to the sea-level map, it is evident that symbols indicate the presence of thunder-storm effects (Fig. 5B). This signifies the occurrence of thunderous and stormy rainfall resulting from convective disturbances happening above the Sahara region near Mauritania. It can be inferred that the disturbance responsible for the weather conditions on October 9th, 2008, falls under the category of quasi-tropical disturbances often referred to as "Mauritanian disturbances" (CAZALE, 1954). These disturbances, due to their southeast-northwest flow, reached the country through eastern Morocco, leading to historically significant rainfall in these areas (HANCHANE, 2012). Typically, this type of disturbance seldom travels extensive distances, making its arrival in the Nekor basin a rare occurrence. However, when it does reach the region, it brings exceptionally high levels of precipitation, as exemplified on October 9th, 2008, when precipitation approached 120 mm. This type of disturbance is known to be particularly active southeast of the High Atlas Mountains (EL BAYE, 1990).



A. Morphology at 500 hPa level



B. The situation at sea level

Fig. 5. The atmospheric conditions giving rise to the weather pattern on October 9th, 2008

Analyzing the 500 hPa topography patterns reveals that the Nekor Basin experienced a resurgence of instability starting from October 19th, attributed to a sharp polar descent. However, the impact of this disturbance became significantly more pronounced from October 22nd onwards when the northern part of the Moroccan domain fell under the influence of a "Cut-off Low." This atmospheric setup facilitated substantial rainfall across various stations in the Nekor Basin, spanning five days from October 22nd to October 26th. The heavy rainfall resulted in flooding, leading to the overflow of the valley. These hydrological events had impacts on the facilities and infrastructure in the Nekor Basin, as shown by images A, B, and C in Fig. 6.

A closer examination of meteorological conditions at the surface level (0) on October 19th indicates the presence of a low-pressure system (973 hPa) situated north of the Atlantic Ocean, accompanied by several cold fronts. Commencing on October 22nd, some of these fronts advanced through the Atlantic interface, following a general northwest-to-southeast trajectory before reaching the Moroccan region. This progression resulted in rainfall occurring in several locations during this period.



A. Bayenty Bridge before October 24th, 2008



B. Bayenty Bridge after October 24th, 2008



C. Flooding in the plain of Nekor, northeast of the basin rural community "Trougout"



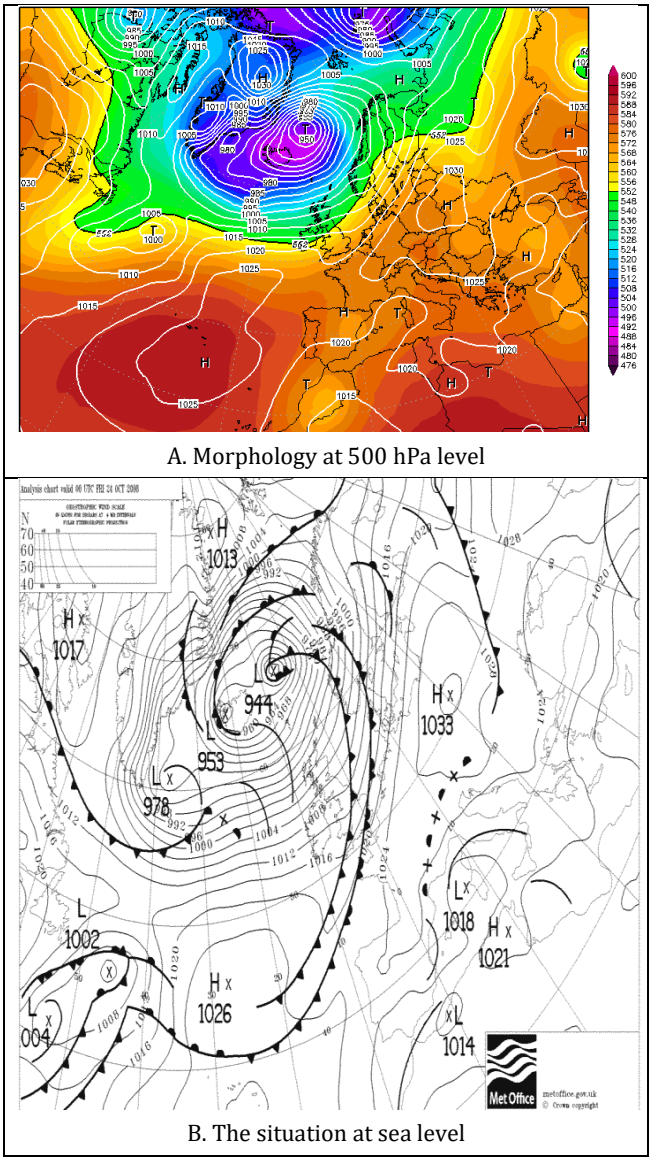
D. The extraction of stones from Wadi Al-Nekor

Fig. 6. Flood manifestations resulting from the last third of October 2008 (Photos by A. Al Mashoudi)

Starting from October 23rd, the low-pressure system stabilized over the Mediterranean Sea and underwent notable changes related to its stability characteristics. It's widely recognized that Mediterranean disturbances typically originate above the Mediterranean Sea, particularly in the vicinity of the Balearic Islands and the Gulf of Genoa (ARRAJI, 1995). These disturbances exhibit three key characteristics: the formation of a vortex manifested in the circular side of cloud masses, a propensity to disrupt traffic movement, and the inflow of warm tropical air (VIGNEAU, 1987). Mediterranean disturbances are primarily fueled by the influx of warm air from the south, serving as a crucial driving and amplifying factor for the lower troposphere structure (EL BAYE, 2022).

The weather conditions we are attempting to elucidate are closely tied to the swift transformations that transpired within the atmospheric structure between October 19th and October 24th. This sequence initiated as an Atlantic pattern and subsequently transitioned into a Mediterranean one. Several factors contributed to this transition, with the most prominent being the stability of the Siberian high-pressure system situated over Europe. This stability led to the confinement (blocking) of the Mediterranean disturbance from three directions – north, northwest, and east – owing to the crescent shape assumed by this high-pressure system. Consequently, the low-pressure system remained anchored over the Mediterranean Sea for an extended period. The northeastern coastal regions, in particular, experienced the inflow of air with a northeast-to-southwest trajectory, giving rise to the phenomenon known as the "return from the east" (Fig. 7AB). This phenomenon is often

manifested by the presence of a "Cut-off Low" on the 500 hPa chart, which can be positioned either over the sea or the continent. The eastern Rif region, in particular, greatly benefited from this atmospheric configuration, a feature notably observed starting from October 23rd, 2008.



A. Morphology at 500 hPa level

B. The situation at sea level

Fig. 7. The atmospheric conditions giving rise to the weather pattern on October 24th, 2008

3.4. Discussion

The study highlights the significant impact of weather variations on rainfall patterns in the Nekor Basin, revealing the region's susceptibility to rapid weather changes and the consequential fluctuations in precipitation. Notably, the observed increase in precipitation during specific case studies had a profound effect on the Mohamed Ben Abdelkrim Al Khattabi Dam (MBAK), posing both challenges and opportunities for managing water resources. The increased water inflow, exceeding 5 M/m^3 in some instances, highlights the dynamic nature of the weather patterns affecting the dam.

In light of these findings, the importance of accurate weather forecasting and monitoring in the Nekor region is emphasized. The ability to predict and respond to changing weather patterns is crucial, especially in scenarios where heavy rainfall can lead to flooding. The study reveals the dual nature of challenges and opportunities faced by the Nekor Basin in managing its water resources. It sheds light on the challenges posed by extreme weather events and emphasizes the need for effective flood mitigation strategies. Additionally, the study highlights the potential for improved forecasting and resource management in the region.

The analysis of various weather patterns during the study, including tracking changes in air flow at the 500 hPa level, the formation of low-pressure systems, and atmospheric stability at sea level, provides a nuanced understanding. Cut-off Lows (COLs) are identified as the main producers of extreme precipitation in the Nekor region, aligning with findings from studies in the northern Mediterranean basin (Llasat et al., 2007; Ferreira, 2021). The COLs are common features of Mediterranean meteorology in warm months and are often related to severe weather (Porcù et al., 2007).

Furthermore, the study highlights the substantial role played by sub-tropical disturbances, known as "Mauritanian disturbances," originating from the northern Sahara. These disturbances, recognized by Moroccan meteorologists, travel in a specific direction (SSW-NNE) (Cazale, 1954), manifesting as swift and consecutive waves in the southeast of the Moroccan High Atlas mountain range. Their influence, coupled with cold air over North Africa, significantly impacts precipitation patterns. Terrain barriers, as emphasized by Arraji (1995), play a crucial role in activating these weather systems.

4. Conclusions and recommendation

The study emphasizes the crucial role of reliable meteorological data in comprehending and responding to dynamic weather conditions, particularly in the context of water resource management decisions. In light of the findings, there is a compelling need for additional research within the Nekor Basin to delve

deeper into the intricacies of weather patterns and their impact on water resources. Subsequent studies have the potential to contribute to the development of more robust forecasting models and strategies for effective flood management.

This research also provides a promising avenue for the improvement of water resource management in the Nekor region. By incorporating advanced weather forecasting tools and proactively implementing flood mitigation measures, the region can enhance its readiness for extreme weather events. The study highlights the intrinsic value of meteorological analysis in unraveling the complex interplay between weather patterns and water resources. Through continuous analysis and interpretation of weather data, the region can adapt to evolving conditions and formulate sustainable water management strategies.

In conclusion, this study serves as a foundational step towards a more holistic understanding of the intricate relationship between weather, water resources, and sustainable management in the Nekor Basin. It not only offers valuable insights but also establishes a solid groundwork for future research and practical applications in the region.

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