INTERNATIONAL JOURNAL OF ENVIRONMENT
Volume-5, Issue-3, June-Aug 2016 ISSN 2091-2854
Received:23 February *Revised:14 June* *Accepted:20 August*

CAUSES AND CONSEQUENCES OF THE NOVEMBER 2014 TORRENTIAL RAINS IN THE CENTER & SOUTH OF MOROCCO

ROMAN Abdellatif and AIT HSSAINE Ali
Laboratory of Geo environment and Development of Arid and Semi-Arid Zone (GEDEZA),
Department of Geography, University of Ibn Zohr, Agadir, Morocco
Corresponding author: a.roman@uiz.ac.ma/aithssaine55@gmail.com

Abstract

In November 2014, the central and southern Morocco have experienced extreme rainfall reached 287 mm and exceeded 240 mm on the last ten days of that same month .In Agadir city the annual average precipitations is 236 mm. Through reading and analysis of a long chain of Agadir station climate data (100 years), it becomes clear that the exceptional rainfall, which resulted in catastrophic damage with colossal human as well as material losses, is by no means an isolated case. In fact, the region had experienced similar or greater amounts of rainfall before. If Agadir was not significantly damaged by the floods on 28 November 2014, compared to the nearby towns such as Ait Melloul, Tiznit and Sidi Ifni, it is because of the preventive measures taken to protect the city against such hazards, especially after the floods that the city of Agadir witnessed in December 2010. In this respect, we should especially mention the planning of drainage basins facing the city by building hilly dams and water disposal canals.

Key words: Morocco, Agadir, rainfall, meteorological, floods, drainage, basins.

Introduction

Even if drought is a structural phenomenon in Morocco, the country remains subject to significant floods that may be very damaging to its infrastructure and can cause many victims among the population. The city of Agadir is not an exception despite its geographical position as a southern city (30 ° 25' N, 9 ° 36' W) in the foot of the High Atlas Mountains, which represent a barrier to the cold North Atlantic front. Moreover, Agadir is located in the Souss Valley, which is open onto the Atlantic Ocean (Saidi, 1994). It belongs to the semi-arid area where the annual normal rainfall average does not exceed 236mm.

In November 2014, Agadir and its region witnessed unprecedented cycle of atmospheric disturbances. It witnessed an exceptional rainfall where the amount of rain reached 287 mm and exceeded 240 mm during the last ten days of that same month only. Resulting from these precipitations were dangerous floods with lots of significant material as well as human damage (Lamili, 2014). This event is closely related to the climate changes affecting the planet in the last two decades (Ait Hssaine, 2013; Meddi et al., 2009; Amraoui et al., 2011; Sebbar et al, 2011, 2012).

Throughout this paper, we will attempt to explain the climatic factors behind these natural catastrophes by studying and analyzing the meteorological maps and the meteorological conditions-related satellite photos, taken especially on November 28, 2014 when the amount of rain reached record figures. The objective of the current study is to analyze the peculiar features of the weather situation in November 2014. It is based on the analysis of satellite images, weather charts and statistics of the last 100 years. It also aims at determining whether that phenomenon is rare or exceptional as well as the probability of return of such a phenomenon.

Finally, we wish to understand why the material damage and human losses were heavy in the areas and nearby towns such as Tiznit, Sidi Ifni and Guelmim, but not in the city of Agadir.

It is worth mentioning that the source of our data is provided by the Moroccan National Meteorological Office, Meteorological Office in Agadir, Souss Massa Water basin Agency in Agadir (2015), as well as the Internet websites together with our field observations.

1- Ordinary Atmospheric State

1.1- Longitudinal Geographic Position

Morocco's position between latitudinal lines 20° and 35° north (Fig.1) gives it a high importance not only because it is exposed to hot tropic atmospheric impacts coming from the south and the cold atmospheric impacts coming from the north, but also because of its huge geographical expansion, due to which the country witnesses varied bioclimatic levels ranging from the mild level to the arid level passing by sub-mild, sub-arid and arid bioclimatic levels. Morocco, thus, is distinguished by a Mediterranean climate in the North and North West and an arid climate in the South and South East.

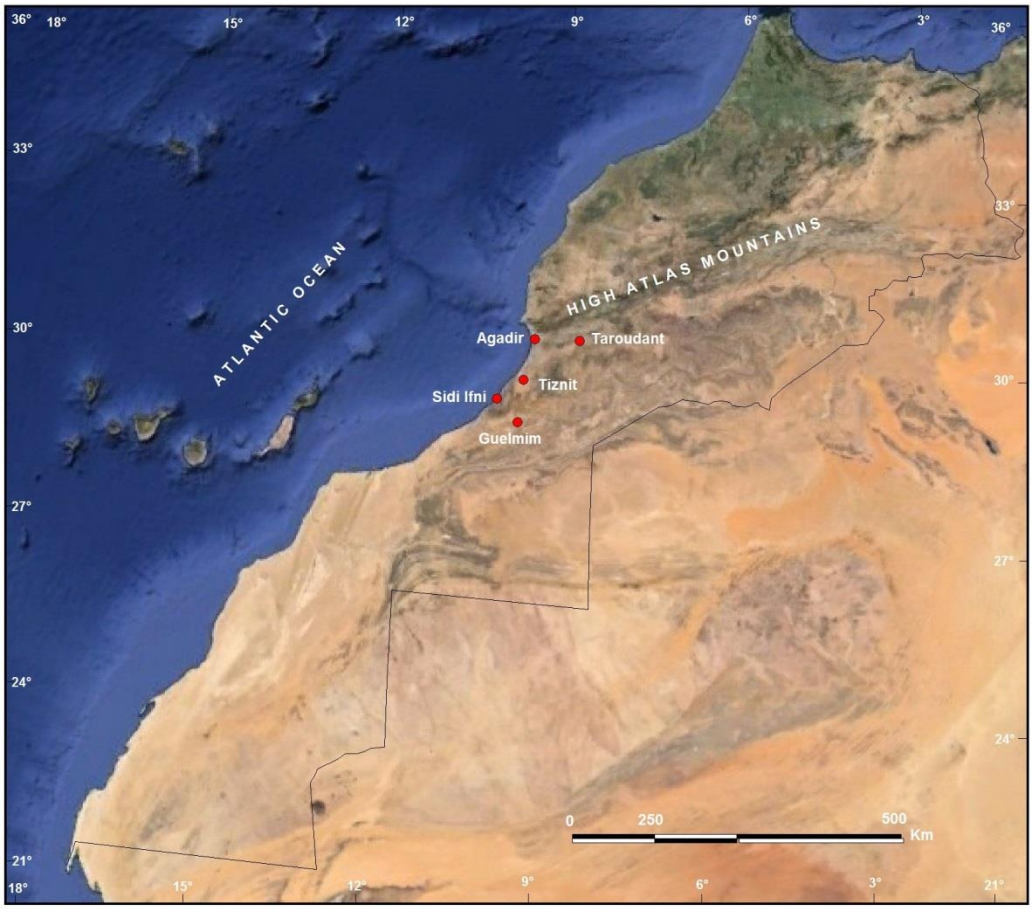
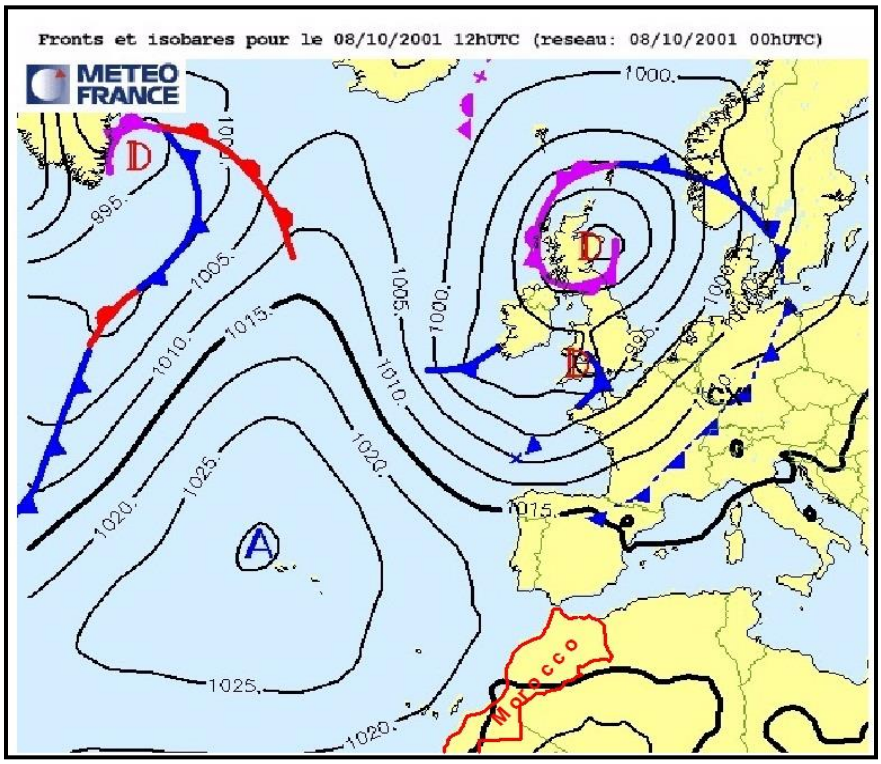


Figure 1. Agadir's location in the Morocco (Map by Google Earth modified)

1.2- Morocco's Position According to General Atmospheric Circulation

Morocco plays an important part in the general atmospheric circulation and the North Atlantic air circulation as to the distribution of the rainfall characterized by its time and place-bound irregularities. While this rainfall is heavy in autumn and winter, it becomes scarce as we are gradually heading from the North to the South (Cote et al, 1966). Morocco is situated in the South of the polar front, resulting from the coming together of the north cold polar air masses and the Atlantic Ocean's moisturized warm sea arctic masses. This front advances the Iceland Depression, which is concentrated over the island of Iceland north of the Atlantic Ocean. Morocco is also situated in the east of the Azores Pressure, which is concentrated over the Azores Islands covering a huge zone extending from the east of the Atlantic Ocean to its west (Fig. 2).



Reference: METEOFRANCE (2001)

Figure 2: Morocco's position with regard to the Azores pressure (A) and Iceland depression (D)

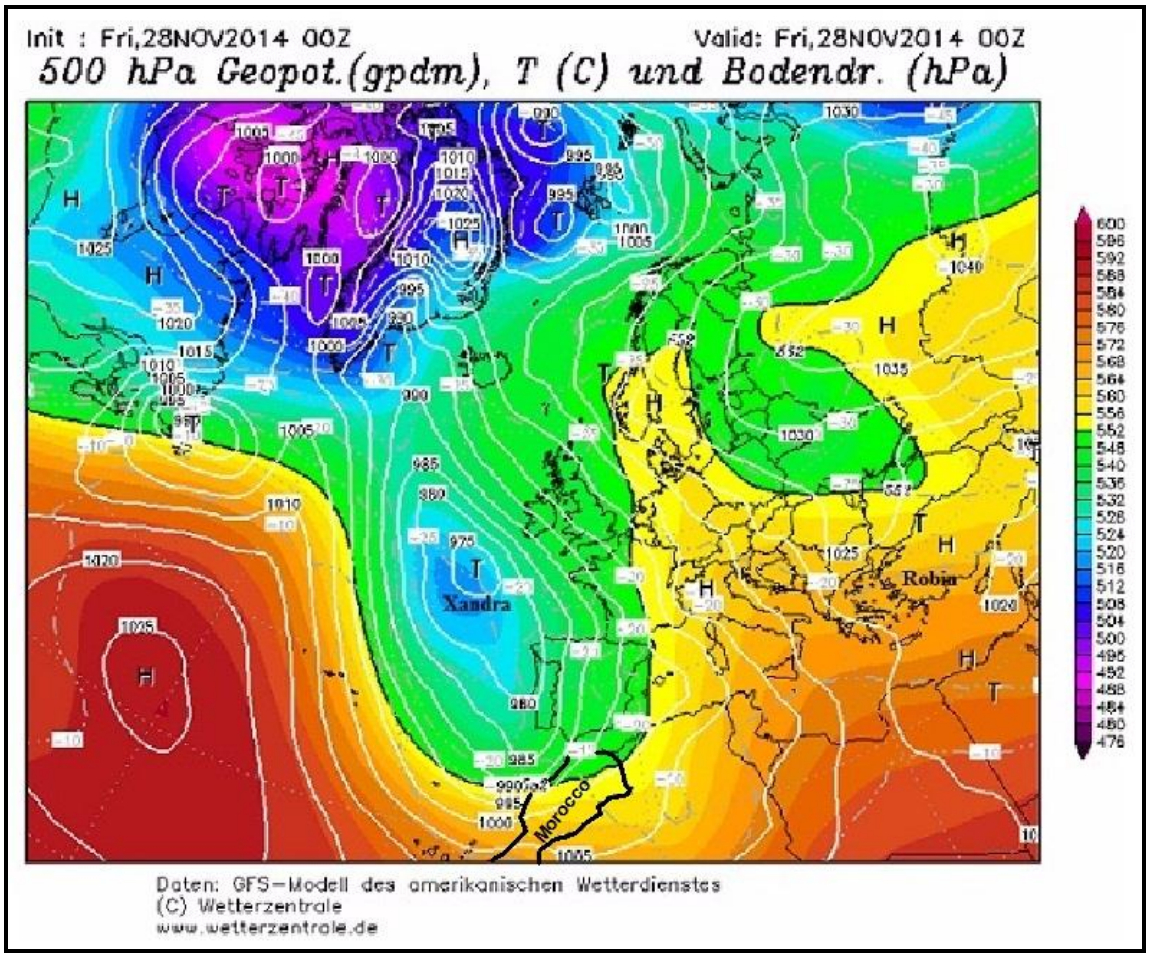
These two situations greatly affect the climatic progression in Morocco in general and the rainfall system in particular. In the normal state, clearly exemplified during summer time, Morocco is under the Azores Pressure which is considered as «preserving shield » protecting the country against the coming of air turbulence from the North and the North West via the Atlantic Ocean.

In winter, the Azores Pressure decreases, contracts and moves southward or south west, leaving ground to the turbulent, rainy Iceland Depression which becomes larger eastward in the direction of Europe or southward in the direction of the Iberian Peninsula and the north of Morocco? By contrast, it rarely reaches the centre and the south of the country. Accordingly, the north of Morocco is much luckier regarding the possibility of having rainfall compared to the centre and the south of the country inasmuch as the annual precipitation averages which exceed 1000 mm in the Rif Mountains and go under 100 mm in the southern areas.

The general rule is that the rainfall goes down from the north to the south because the atmospheric turbulence, due to the Iceland Depression, rarely reaches Morocco. If it ever does, the northern areas remain the sole beneficiary.

2- Climatic Reasons behind Morocco's End November 2014 Rainfall

November 2014 is well known today as the month of atmospheric turbulence par excellence (Chillymanjaro, 2014) due to the exceptional rainfall witnessed by Morocco in general and by numerous central and southern Moroccan regions in particular. It happened mostly during the last week of the same month when the meteorological stations recorded unprecedented figures in these regions. The annual amounts of rainfall outnumbered that of the regions' average in a very limited span of time.



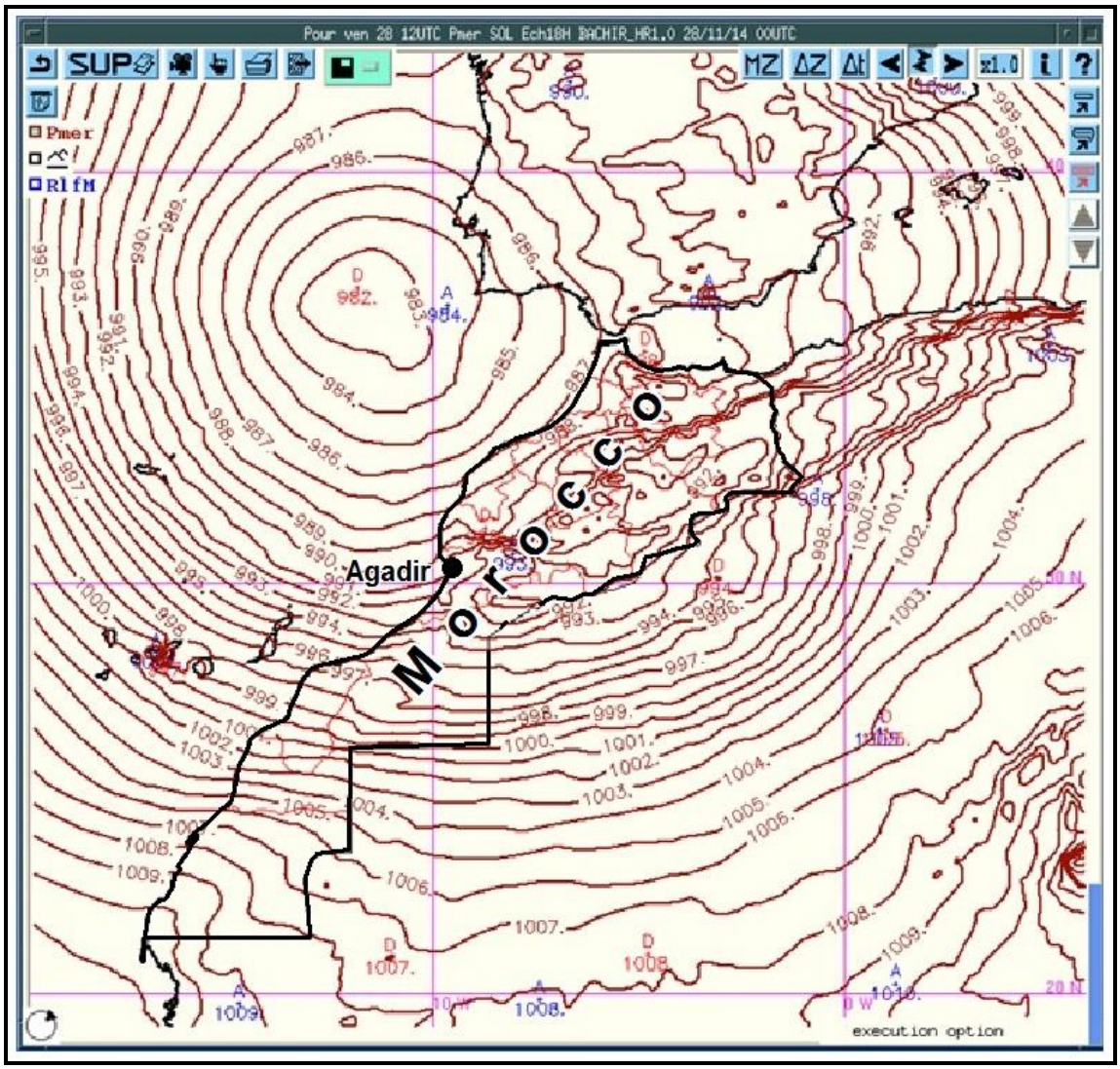
Reference: http://www.wetlerzentrole.de

Figure 3: Atmospheric pressure map at the level of 500 Hectopascal on 28 November 2014.

The profound study of the satellite photos and the meteorological maps of November 28, 2014 clearly show a rare atmospheric situation as we notice the contraction and regression of the Azores Pressure (H in red color, left of picture) towards the South West besides getting separated from the Robin Pressure located over Eastern Europe and Russia. The latter was an obstacle and a blockade before Xandra Depression situated over the Atlantic Ocean, stopping it from moving towards the East, within the frame of a normal zoned air cycle, and making it move southward in the direction of Morocco in the form of cold humid air masses exemplified in a deep valley (Thalweg) which is considered as an extension of the Iceland Depression of which the atmospheric pressure reached its lowest levels as its value was 982

Hectopascal in the centre on November 28, 2014, 990 Hectopascal in Agadir and 995 Hectopascal in Guelmim (Fig.4), (Since 1954 the Free University of Berlin's Meteorology Institute was the first to have suggested naming the atmospheric high and low pressures over the Atlantic Ocean and Europe to facilitate their observation and following-up on the meteorological maps. Robin and Xandra: names of pressure and depression respectively, found on the German maps, and were behind the atmospheric situation Europe and Morocco experienced by the end of November 2014).

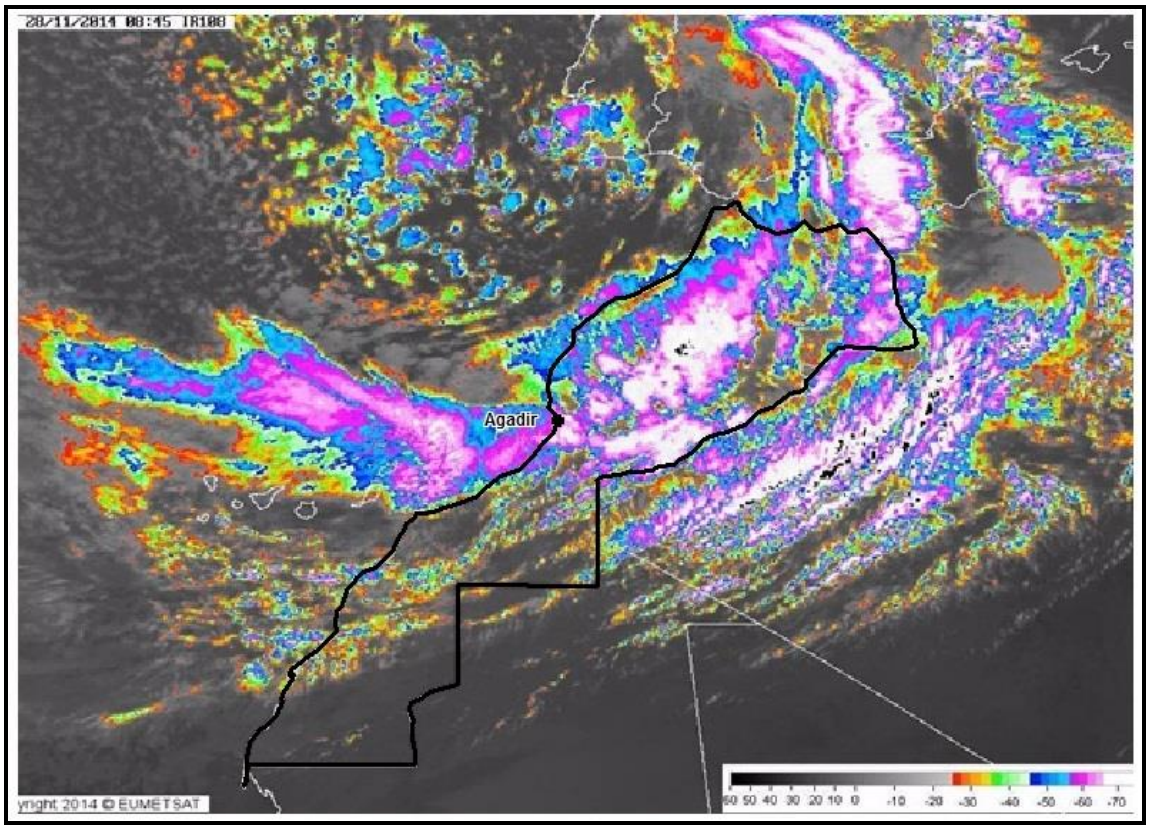
These atmospheric pressure figures are a lot lower than the average pressure, namely 1015 Hectopascal. Morocco seldom witnesses such figures, especially in the Souss Massa region and the southern regions where the pressure reaches its lowest levels. These figures are usually recorded over Iceland or the British Isles. Its presence in these central and southern Moroccan areas reflects the power of the fluidity of the air masses coming from the north, which to collide with the warm air masses coming from the tropic regions. This collision of two contradictory masses, as to the physical characteristic (temperature degree and humidity rate), results in violent rainfall.



Reference: Moroccan Meteorological Office.

Figure 4: Air Pressure on the Surface on November 28, 2014

The passing of this atmospheric turbulence by the Moroccan coasts makes it less stable and more turbulent, seeing the temperature emerge from the base, provided by the Atlantic Ocean's warm surface waters at these low levels of latitudes as if it were about a tropic air turbulence (Fig.5).



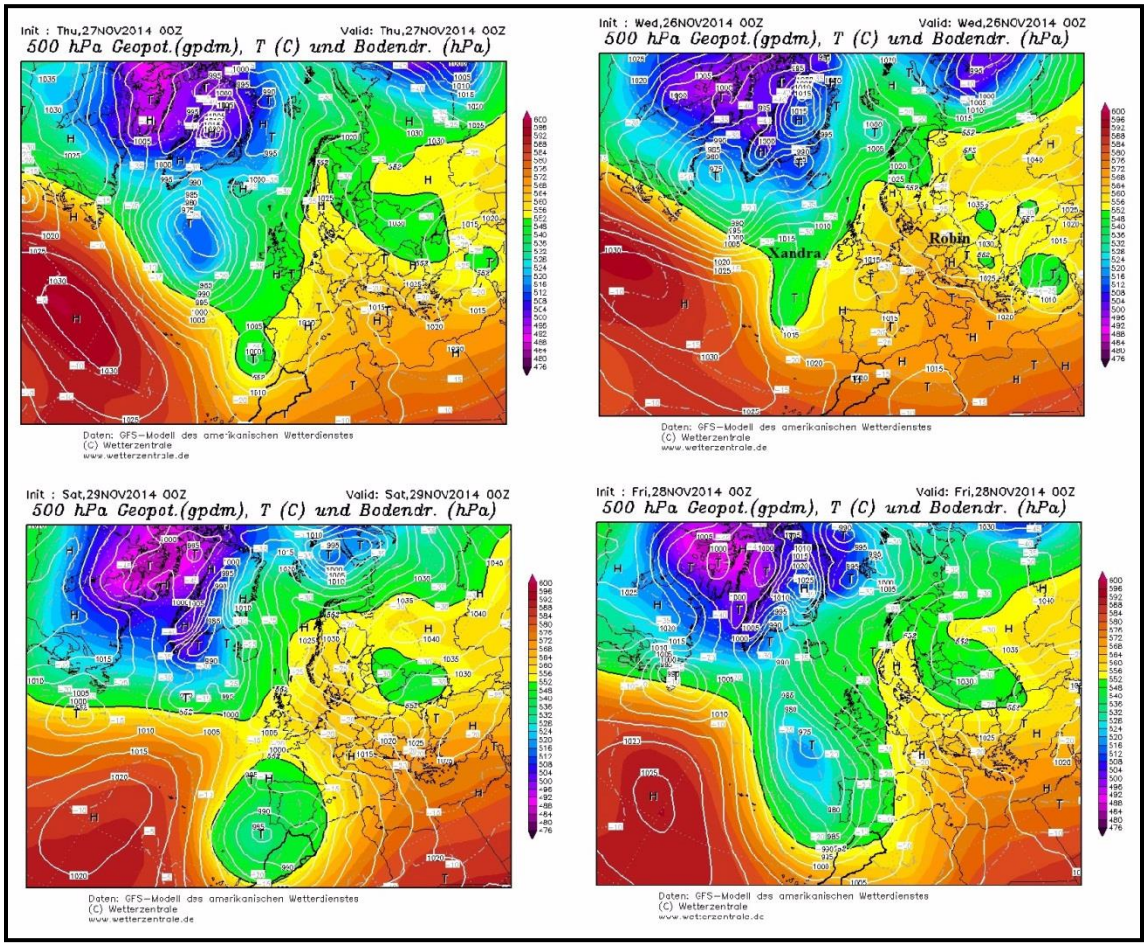
Reference: www. eumetsat.com

Figure 5: November 28, 2014 Satellite Image (EUMETSAT)

This unusual state is corroborated by the analysis of the high atmosphere maps at the 500 Hectopascal pressure level of the 26, 27 and 28 November 2014 (Cf. Fig. 6). As we notice, the falling out of "the cold air drop" (Cold Drop) that went beyond the Iberian Peninsula towards the centre and the south of Morocco in the form of a deep valley due to the decrease in the speed of the evaporating current and its inclination towards the south, taking a cavity shape, which is an anomalous state that rarely happens. This is the consequence of a defect in the air dynamic system related to "North Atlantic Oscillation" (NAO) as it is rare that the cold air drop reaches such low latitude levels. According to some researchers (Attilah et al, 1995), the defect which happens at the level of the North Atlantic Ocean's air cycle is caused by the change in the temperature's degree of this ocean's surface waters. If the North Atlantic

Oscillation records positive and powerful signs, it results in severe drought; however, if the same sign is negative, it results in important rainfall.

Also, what distinguishes this exceptional atmospheric state is the duration of the penetration of this atmospheric turbulence into the centre and the south of Morocco which lasted three days (26, 27 and 28 November) resulting in unprecedented record rainfall. The state didn't become normal again until November 29, 2014.



Reference: www.wetlerzentrole.de

Figure 6: The Falling out of the Cold Air Drop Development in the Direction of Morocco in the Form of a Valley (Thalweg) on 26, 27 and 28 November, 2014

This state resulted in exceptional rainfall and floods in the centre and the south of Morocco, where the amounts of rain registered record figures, reaching, on a single day (November 28, 2014), 100.5 mm in Tiznit, 63 mm in Taroudant and 65 mm in Agadir (Fig. 7)

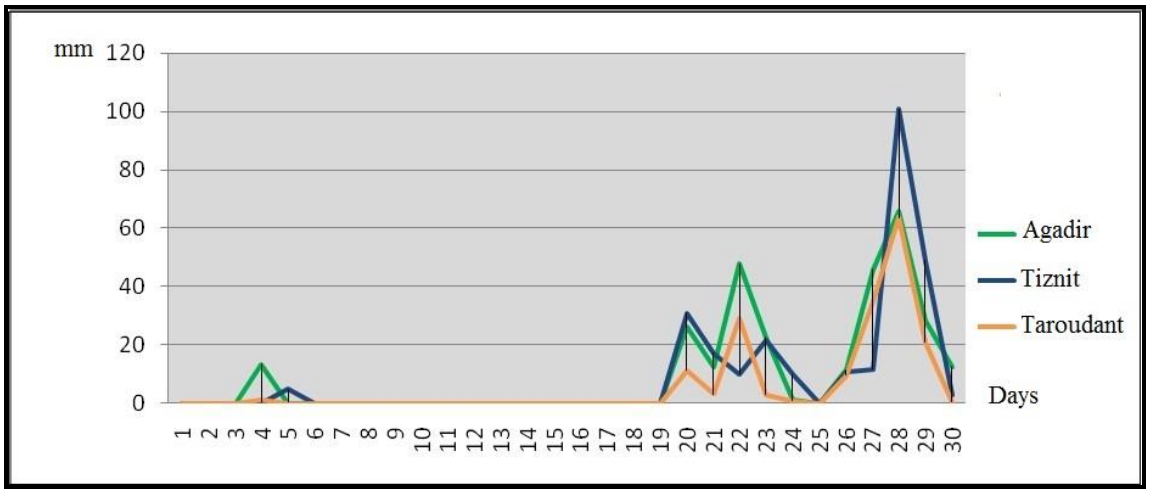


Figure 7: Quantity of Rainfall during November 2014 in Agadir, Tiznit and Taroudant

The question that poses itself now: is the rainfall November 2014 witnessed exceptional and unprecedented or is it only a rare state?

To answer to this question, we will read and analyse the statistical data concerning Agadir precipitation.

3- Statistical Data Analysis of Agadir Rainfall

3.1- Analysis of Interannual Rainfall Data

Through a reading and an analysis of a long chain of Agadir station climate data (100 years, from 1915 to 2014), it becomes clear that the exceptional rainfall, which resulted in colossal human as well as material damage, is by no means an isolated case (Cf. Fig. 8).

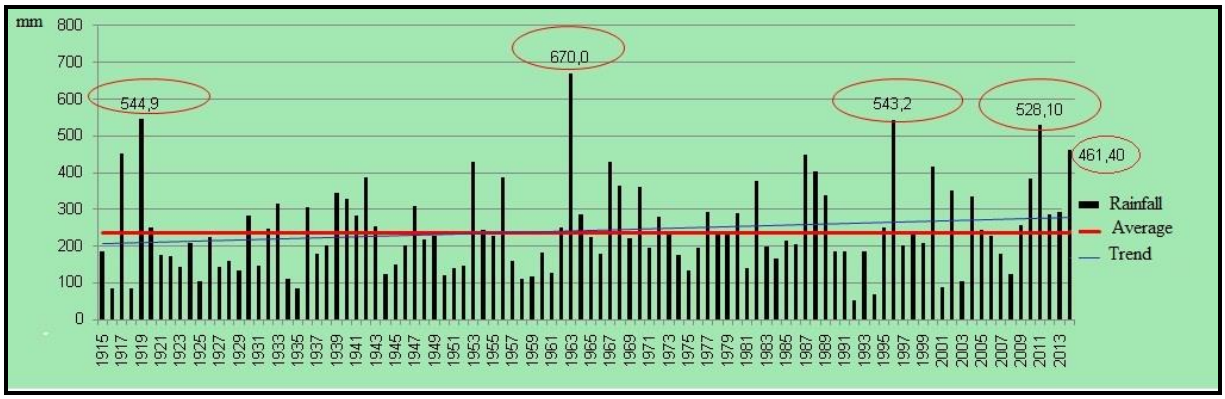


Figure 8: Interannual Rainfall in Agadir from 1915 to 2014

The region had witnessed similar or even more amounts of precipitation in the past. If we consider the interannual distribution, we notice that Agadir Station had registered record figures. As a case in point only, the global yearly rainfall had reached 554 mm in 1919, 670 mm in1963, 543 mm in 1996, and 528 mm in 2010.

3.2- Analysis of Monthly Rainfall Data

If we take into account the monthly recorded amounts in the city of Agadir (Fig.9), always as a case in point only, the record precipitation had reached 289 mm in November, 1919; 214 mm in December, 1963; and 357 mm in December, 2000. These figures exceed by large the annual average of the same station.

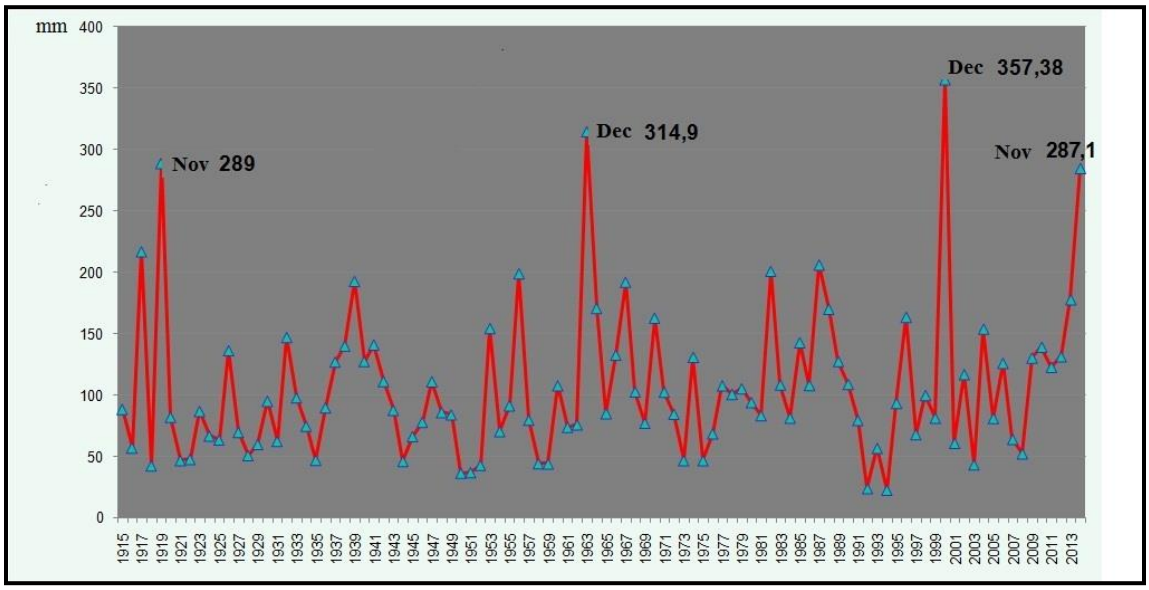


Figure 9: Monthly Record Rainfall in Agadir (1915-2014)

The study of Agadir violent rainfall-related statistics (1915-2014,fig.10) reveals a 13% likelihood of the coming back of rainfall exceeding 10 mm in January, 12% in December and 10% in November. This proves that there is a big likelihood of the coming back of the floods in the centre and the south of Morocco, especially under the climatic changes in the world, in general, and in Morocco, in particular (Agoumi, 1988, 1999).

	JAN	FEV	MARS	AVR	MAI	JUIN	JUIL	AOUT	SEPT	OCT	NOV	DEC
>100 mm	13	7	4	4	1	0	0	0	1	3	10	12
>200 mm	1	0	0	1	0	0	0	0	0	0	2	3
>300 mm	0	0	0	0	0	0	0	0	0	0	0	2

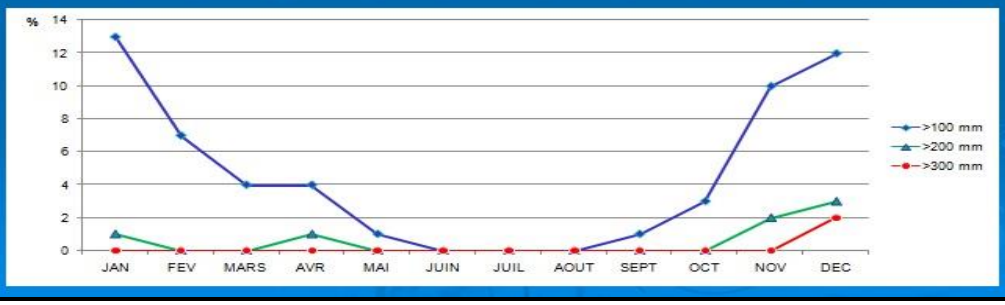


Figure10: Probability of Powerful Rainfall in Agadir Station (%) (1915-2014)

3.3- Analysis of Daily Rainfall Data

If we consider Agadir-Inzegane registered record rainfall during 24 hours between 1939 and 2010 (Tab.1), we notice that the amounts of November 28, 2014 rainfall were not an exceptional or unprecedented case; the same station had registered what equaled or exceeded them by far. For instance, 105,5 mm had been registered on December 17, 1939 and 104,5 mm on February 1, 2009.

Table 1. Agadir-Inzegane Station Daily Record Rainfall between 1939 and 2010

Date	**17/12/1939**	**6/11/1966**	**12/4/1982**	**16/10/1988**	**14/3/1999**	**1/2/2009**	**6/1/2010**
mm	**105,5**	**77**	**97,9**	**56,9**	**59,1**	**104,5**	**69,8**

Reference: Meteorological Office in Agadir.

4- Results and Measures Taken to Limit Flood Hazards in Agadir

4.1- Results of November 2014 Rainfall

It is worth mentioning that November 28, 2014 rainfall was not isolated as it had been preceded by other rainfall in the beginning of this month, which became more severe the last week of the same month. The monthly total rainfall reached 287, 1 mm in Agadir, 269,3 mm in Tiznit and 178,1 mm in Taroudant. This means that the earth was approximately saturated and was not ready to receive more rainfall.

As we know, the south of Morocco is a fragile natural area, characterised by an extremely deteriorated soil, and the flora protecting this soil from erosion is itself fragile and degraded. This is why the exceptional rainfall witnessed in the centre and the south of Morocco, in general, and the Souss Massa region, in particular, resulted in huge floods, because of which the human and material damage was great, especially with respect to the infrastructure and the fragile structures. The material losses were important mainly for the buildings set by the banks of the rivers and the flood-endangered regions under the pressure of population growth, poverty and urbanisation. For the human losses, the number of casualties reached 47 dead (According to Morocco's Ministry of Interior's official statistics). The majority of these casualties were due to some careless public transporters who preferred to take risks, putting the passengers' lives at stake, to cross the rivers and the vulnerable bridges in the midst of a lack of a culture dealing with such natural catastrophes, let alone the fragile infrastructure that is no longer capable of fulfilling its functions, especially in the provinces of Guelmim, Tiznit and Taroudant as well as the suburbs of Agadir.

The amounts of rainfall different regions in the centre and the south of Morocco experienced a positive impact on thegroundwaters and the quantity of waters in the dams, which have been suffering a terrible shortage since the end of the summer of 2014. The waters in the dams reached record figures on December 1, 2014. Listed below are some examples (Souss Massa Water basin Agency):

i. Youssef IbnTachafine Dam 103%
ii. AhlSouss Dam 102%
iii. MokhtarAssoussi Dam 99%
iv. Aoulouz Dam 103%
v. Imi Al Khank Dam 102%
vi. MoulayAbdellah Dam 104%

These dams were by large capable of limiting the flood hazards that these regions witnessed. They also participated in saturating the groundwater of the Souss Plain and in saving about 55 million m^3 of pumping waters besides its myriads benefits for the mountains inhabitants, the flora and the ecology system.

Figure. 11 (Pictures) Illustrating the Losses of Some Regions in the Centre and the South of Morocco

4.2- Measures Taken to Limit the Flood Hazards in Agadir

Despite the important amounts of rainfall, Agadir was not significantly damaged by the floods on November 28, 2014, as had been the case in the past, compared to the nearby towns like AitMelloul, Tiznit and Sidi Ifni. This was possible thanks to the city's policy and the preventive measures taken to protect it against such hazards and to prevent such natural disasters, especially after the floods which the city of Agadir had witnessed in December and February 2010 (77 mm and 139 mm, respectively). We should, especially, mention here the planning of the drainage basins facing the city and their protection by building three hilly dams on the streams penetrating Agadir's neighborhoods like Tamlast River, Lahouar River and Al Ghazoua River in addition to the two canals for the disposal and redirection of waters towards other rivers and streams (RAMSA, 2010). Figure 12 shows protection of Agadir

from floods by means of small dams and hilly lakes. Rainfall damage in Agadir in November of 2014 was much less important than that of December 2010.

Figure 12: Protection of Agadir from Floods by Means of Small Dams and Hilly Lakes

Agadir's experience, with respect to the preventive measures to control the flood hazards, greatly participated in limiting the danger of such natural catastrophes inasmuch as no human losses were recorded and cases of blocked roads, compared to the past, were rare regardless of the record amounts of rainfall. These measures may be an example to follow, and to make use of, in the most afflicted regions like the towns of Guelmim and Tiznit because of the exceptional rainfall.

Conclusion

The rainfall in the centre and the south of Morocco experienced during November 2014 were both important and violent. Besides, they were not concentrated in time. On the contrary,

they were characterized by their continuation since the beginning of the month and increased in November 28 of that same year. The weather forecast stations registered record figures during that day.

The atmospheric state behind this rainfall was the blockade formed by the Azores Pressure settled over Europe by preventing the Iceland Depression from moving towards the east and forcing it to head southward in the direction of Morocco, in the form of a deep valley after the contraction of the Azores Pressure towards the South West.

This rare climatic state resulted in important rainfall that reached its highest levels. Morocco had not known such a state for a long period of time. This rainfall resulted in disastrous floods both in the centre and the south of Morocco, where fragility at all levels, natural and human, is the main characteristic of these regions. This makes them suffer colossal material and human losses.

What makes some people consider this precipitation as exceptional and make a fuss about it is the shortness of the human memory on one hand and the role the media and the modern means of communication play in broadcasting these natural disasters on the other hand. Thanks to these means and modern technologies, the news broadcasts and transmits events and incidents a lot faster in live pictures and sounds, a fact that has a huge impact on the public. This very thing was impossible in the 30's and 60's of the last witnessed similar dangerous floods.

References

Agoumi, A., 1988. Changements climatiques et ressources en eau. Rapports nationaux établis dans le cadre du projet régional du FEM réalisé par le PNUD. pp.163-182.

Agoumi, A., 1999. Introduction à la problématique des changements climatiques. Document établi dans le cadre d'une consultation pour la coordination nationale du projet régional du FEM réalisé par le PNUD. pp.3-43.

Ait Hssaine, A., 2013. Le Souss (Maroc) entre le réchauffement climatique et la rareté de l'eau : quelle prospective territoriale ? GéoMaghreb, n°9, pp. 3-17.

Amraoui, L., AdamaSarr, M., and Soto, D**.,** 2011.Analyse rétrospective de l'évolution climatique récente en Afrique du Nord-Ouest. Physio-Géo, Volume 5, pp. 125-142.

Aresmouk, M. , 2005.Gestion des risques liés aux inondations. Système de prévision et d'alerte aux crues du bassin de l'Ourika,Marrakech. Communication au séminaire technique international: La gestion intégrée des ressources en eau dans les régions méditerranéennes et en Afrique du Nord (Marrakech, Maroc), p.40.

Attilah, A., Abdellaoui, R., and Boufdili, T., 1995.Interactions océan-atmosphère et dynamique climatique globale. Revue GEO OBSERVATEUR n°6.pp. 16-34**.**

Chillymanjaro, 2014.New round of severe weather and flooding for Morocco, Spain, France, Italy and parts of Balkan Peninsula. www.thewatchers.adorraeli.com. (Accessed: 30 November 2014).

Cote, M., and Legras, J., 1966.La variabilité pluviométrique interannuelle au Maroc. Revue de géographie du Maroc, n° 10. pp.19-30.

Lamlili, N., 2014. Maroc : inondations meurtrières dans le Sud. Revue Jeune Afrique, http://www.jeuneafrique.com/39934/societe/maroc-inondations-meurtri-res-dans-le-sud/ (Accessed: 24 November 2014).

MEDDI, M., TALIA, A. and MARTIN, C., 2009.Évolution récente des conditions climatiques et des écoulements sur le bassin versant de la Macta (Nord-Ouest de l'Algérie). *Physio Géo*, 354 vol. III, p. 61-84.

RAMSA, 2010. Gestion des crues et lutte contre les risques d'inondations dans le Grand Agadir. Régie Autonome Multi-Services d'Agadir. p.43.

Saidi, M.E., 1994. Genèse et propagation des crues en milieu sub-aride : exemple de l'oued Souss (Maroc). Bulletin de l'Association de Géographes Français, n° 1, p. 94-111.

Saidi, M.E., Daoudi, L., Aresmouk, M.E., Fniguir, F. and Boukrim S., 2010.Les crues de l'oued Ourika (Haut Atlas, Maroc) : événements extrêmes en contexte montagnard semi-aride. ComunicaçõesGeológicas, vol. 97, p. 113-128.

Saidi, M.E., Bouloumou, Y., ED Daoudi, S., and Aresmouk, M.E., 2013.Les crues de l'oued Issil en amont de Marrakech (Maroc), un risque naturel récurrent. EuropeanScientific Journal, vol. 9, n° 23, pp. 189-207.

Sebbar, A., Badri, W., Fougrach, H., Hsain, M. and Saloui, A., 2011.Étude de la variabilité du régime pluviométrique au Maroc septentrional (1935-2004). Sécheresse, vol. 22, nº 3, p. 139-148.

Sebbar, A., Hsain, M., Fougrach ,H. and Badri, W., 2012. Étude des variations climatiques de la région centre du Maroc. In : Les climats régionaux : observation et modélisation, Actes du XXVème Colloque de l'Association Internationale de Climatologie (Grenoble), S. BIGOT et S. ROME édit., p. 709-714.