METEOROLOGICAL PATTERNS AND FOG WATER COLLECTION IN MOROCCO AND THE CANARY ISLANDS

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With 8 figures, 4 tables and 4 photos
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Summary: The aim of this study is to characterize the synoptic weather patterns that justify fog water collection on the coast of Morocco and the Canary Islands. In spite of the fact that they are only 200 km apart and are both affected by the same stratocumulus cloud formation, the latter behaves differently. Furthermore, fog water collection is studied to evaluate its feasibility as a sustainable water resource to satisfy the drinking water needs of a rural population in SW Morocco. The study period was from 2006 to 2010. Standard Fog Collectors (SFC) and the Quarter Fog Collectors (QFC) that were connected to automatic meteorological stations with which hourly and daily data can be recorded were used. The average quantities of collected water were about 10 l/m^2/day at both sites, but there is inverse seasonality since more fog water is collected in Morocco in the winter whereas in the Canary Islands this happens in the summer.

Zusammenfassung: Das Ziel dieses Artikels ist, die synoptischen Wettermuster zu beschreiben, die die Nebelwassergewinnung an der Küste Marokkos und auf den Kanarischen Inseln rechtfertigen. Obwohl diese Gebiete nur 200 km voneinander entfernt sind und beide von den selben Stratokumulus Wolkenformationen beeinflusst werden, verhält sich das letztere anders. Außerdem wird die Nebelwassergewinnung bewertet, um ihre Durchführbarkeit als dauerhafte Trinkwasserquelle für die ländliche Bevölkerung im Südwesten Marokkos festzustellen. Der Zeitabschnitt des Studiums geht von 2006 bis 2010. Die Ausstattung, die verwendet wurde, sind die Standard Fog Collectors (SFC) und Quarter Fog Collectors (QFC), d.h. Nebelwassersammler mit normalem und Einviertel Leistungsvermögen, die mit automatischen Wetterstationen verbunden werden, mit welchen stündliche und tägliche Daten aufgenommen werden können. Der Durchschnitt an Wasseraufnahme betrug ungefähr 10 l/m^2/Tag in beiden Gebieten, jedoch ist der Saisoneffekt umgekehrt, denn es wird in Marokko mehr Nebelwasser im Winter gewonnen, während dieses auf den Kanarischen Inseln im Sommer geschieht.

Keywords: Fog water, rural communities, synoptic weather patterns, Morocco, Canary Islands

1 Introduction

Stratocumulus cloud formation is common in both the Canary Islands (Spain) and along the Atlantic coast of Morocco, where it is referred to locally as *mar de nubes* (sea of cloud) and *tagut* respectively. In both cases, they are advective clouds which acquire the orographic features of the area because of the relief effect and turn into advection fog and mountain fog, (Sharon 1980; Cereceda et al. 2002; Bruijnzeel et al. 2005; Walmsley and Schemenauer 1996; Eugster 2008; Foster 2010); and it is possible to collect part of their liquid content using artificial systems (Photo 1). The water collected for this way can be used by the people living in areas of water shortages for domestic consumption, as in the case of Morocco, or to maintain ecosystems, as in the case of the Madeira or Canary Islands (Schemenauer and Cereceda 1991; Cereceda and Schemenauer 1996; Hutley et al 1997; Dawson 1998; Pascon 1979; Conac 1985; Olivier 2002; Marzol 2008; Marzol et al. 2010; Villegas et al. 2008; Prada et al. 2009).

The source of this cloud formation is connected with the Azores anti-cyclone, subsistence thermal inversion and the cold Canary Current, (Dorta 1993; Marzol 2005). It is of interest, therefore, to know the development processes of the air pressure (localization, frequency and intensity) in the lower layers of the atmosphere in this part of the Atlantic, as this would explain the occurrence of this efficient natural resource.

Since June 2006, the University of La Laguna has been collaborating with the Si Hmad Derham Foundation (Casablanca, Morocco) on a study about the viability of providing drinking water to rural communities in the area around Mount Boutmezguida, in the Aït Maâmrane region of Morocco: This region is 30 km from the Atlantic coast in SW Morocco.

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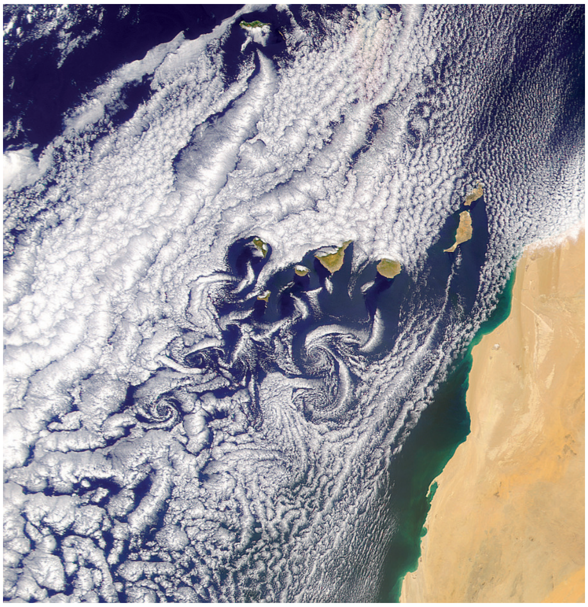

Photo 1: Image from 24th April 2000 showing how the clouds reach the Canary Islands and the Atlantic coast of Morocco. Source: SeaWiFS Project, NASA

The population is made up of twenty communities – 1,550 people and 5,000 animals – which have serious survival problems. On the one hand, the shortage of drinking water complicates not only their domestic tasks, but also their farming and livestock activities; and on the other hand their lands are physically isolated from the rest of the country by the Anti-Atlas Mountains. The scarce economic resources of the region, coupled with a hostile environment (droughts, poor quality soils, small harvests, lack of water, degradation of the vegetation cover due to the absence of appropriate livestock management, poverty, etc.), have led to a high level of voluntary male emigration to the nearest towns in search of construction work and to illegal emigration to Spain (Photo 2).

These circumstances have meant that women have become the sole economic agents as they are the only ones left to perform the hard, physical work on the land in this difficult rural setting (Mernissi 2000; Driss Ben 2004; Ben Attou 2006). This makes them more vulnerable due to the disproportional responsibility they now have for completing the domestic tasks and for looking after the family group. They perform the physically demanding task of fetching the daily water requirements, making round trips of 3 to 4 hours which involve carrying large weights of water back to their homes. Fetching water takes time away from their farming and domestic activities and, even, from their own education and training. This task also consumes more than a third of the energy produced by their daily food intake (Laborde and Morel 1991; Lide 1995; Parish and Funnel 1996; Tazi Sadeq 2007; Ofouémé-Berton 2010).

The ultimate objective of this research project is to provide water to the local population. Large Fog Collectors (LFC) will be built to collect fog water in order to do this. The Si Hmad Derham Foundation has conducted several population surveys and an animal census to quantify the real water needs in the region. Some of the most relevant findings are as follows:

- Women are responsible for getting the water required for drinking, domestic purposes and personal hygiene. They fetch the water from wells at the bottom of the *oueds*. This job is not done by anyone under the age of 16 because of the danger involved at the access to the wells.
- Women are forced to cover more than 1.5 km on each trip, two in the winter and six in the summer.
- The average time taken for the journey to the *oueds* ranges between 90 minutes and two hours, with the added difficulty of crossing steep slopes as the area is mountainous. They have to carry a load of two bramels (30 l plastic water containers).
- Most families do not have tanks to store the water or treat the water to make it suitable for drinking. As a result, the people, especially the children, are exposed to health problems caused by unsafe water.
- The average daily consumption per family, in winter, is 30 litres for drinking and cooking, and about 200 litres for personal hygiene and consumption by the animals. These amounts double in the summer because the animals, mostly goats, need more water every day.

Photo 2: The communes near Mount Boutmezguida experience the effects of erosion, lack of water and poor quality soils (© Marzol)

– The communities in Tamenrout, Agni, N'Zekri, with a total population of 154 adults, and the Medersa Sidi Zekri with 35 schoolchildren, were chosen for the installation of the LFCs because they have the greatest difficulties regarding water availability.

The possibility of providing drinking water to these communities via the LFCs means, without doubt, an improvement in their quality of life and an important collaboration in the sustainable development of a rural population who, because due to the great difficulties they face in their communities, are opting to leave the countryside and their roots to emigrate to the towns.

The work done so far has been to evaluate the amount of potential water that could be collected and to study its annual variations, as this resource is irregular in terms of time. The research project has also studied the relationship between the fog water collected and wind speed and direction, as these are essential meteorological variables on which the water collection of the screens depends. A standard fog collector (SFC) (Schemenauer and Cereceda 1994a) was used in the first phase of the study and the readings were made by local people; later on, a quarter size fog collector (QFC) was installed with the same mesh as the SFC. This QFC is connected to an automatic meteorological station that supplies hourly information on all the variables and makes it possible to decide on the most favourable environmental conditions for the greatest collection of water (see Photo 3). The QFC is a screen of 50 x 50 cm designed in 2002 in order to facilitate the construction and installation on site (Marzol 2002, 2005).

As well as collecting the fog water for human use, the frequency of fog also plays a role in maintaining vegetation, which in the Canaries and on the North African coast is of great botanical value. Along with the Azores, Madeira and Cape Verde Islands, these parts of the world are home to ancient flora that, with a large number of endemic species, flourished in the Macaronesia and in the Afro-European continental territory during the Tertiary period, e.g., *Aeonium aboreum, Dracanea draco, Euphorbia regis jubae, Echium plantagineum, Rumex vesicarius, Erica arborea, Myrica faya, Laurus azorica, Argania spinosa, Acacia gummifera,* etc. (Peltier 1978; Médail and Quézel 1999; Romane 2000; García-Santos 2007; Rivas Martínez 2009; Marzol et al 2010; Ohsawa et al. 2010). The need to ensure the survival of this natural vegetation, which is of great floristic richness, led the Moroccan and Spanish authorities to set out different levels of botanical protection in these areas by means of the declaration of Rural Parks in the case of the Canary Islands (Martín et al. 1995) and Important Zones for Plants (ZIP) in Morocco.

2 Study area, data and methods

Special emphasis in this research work was given to investigating the similarities and/or differences in the behaviour of fog in Morocco and the Canaries, which are 200 km apart. Two experimental sites

Photo 3: The equipment used in the stations at Boutmezguida is a SFC and a QFC (photo on the left) and Anaga there are two QFCs with different meshes (photo on the right). In both cases the meshes are connected to meteorological stations (© Marzol)

were chosen in order to do this: The first site is in Boutmezguida in SW Morocco, 1,225 m a.s.l. 30 km from the Atlantic coast (29°12'30"N – 10°01'30"W); the second site is in Anaga in the NW of the island of Tenerife, 842 m a.s.l. and 4 km from the coast (28°32'09"N – 16°14'11"W) (Fig. 1).

(*Argania spinosa*), alternating with land mainly cultivated with cereals as the soil is poor and there is little rain (Ezaidi and Ait Tirri 2002). The site chosen in the Canary Islands has a damp temperate climate, with about 550 mm of rainfall a year. Its natural vegetation consists of green mountain plants with a

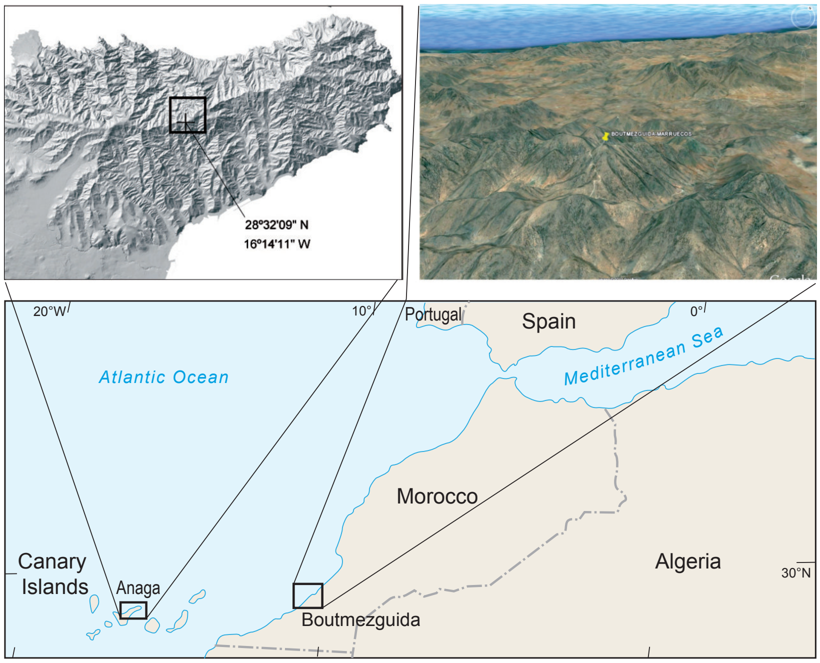

Fig. 1: The location of the study sites in the Canaries and Morocco, which are 4 km and 30 km from the ocean, respectively

The selected site in Morocco has a semi-arid, dry climate with strong daily and yearly thermal contrasts, associated with high annual and interannual variability and torrential rain, although annual averages are not above 150 mm. The vegetation is dominated by large areas of mountain argan trees

predominance of *Myrica faya* and *Erica arborea*, which blend in with vegetable plants, fruit trees and vines cultivated for reasons of self-sufficiency (Marzol 2008) (Photo 4).

The study on fog water collection in Boutmezguida began in June, 2006 with the instal-

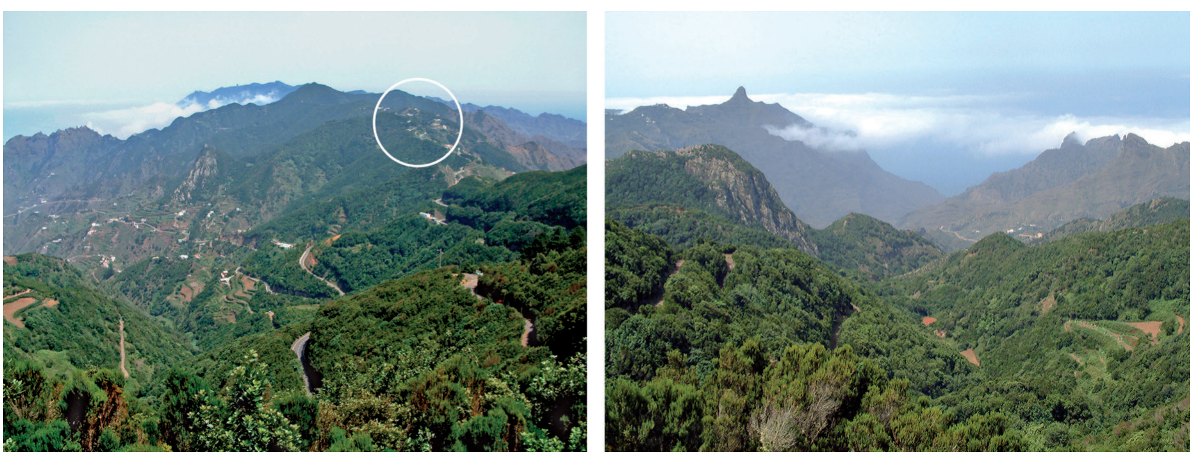

Photo 4: The Anaga station is well positioned (indicated by the circle) to benefit from the clouds coming from the Atlantic which are channelled by the relief (© Marzol)

lation of two SFCs orientated towards WNW (300°) and NNW (340°), because, in the opinion of the local population, these are the most common wind directions (Marzol et al. 2007, 2008). The first of these SFCs was substituted, in September 2009, by a QFC connected to a meteorological station and orientated towards NNW as it was the most efficient direction according to three years of analysis. The SFC directed towards the NNW was kept in place in order to correlate the two sizes of collector. The automatic meteorological station used, the Davis model, records information concerning temperature, humidity, pressure, wind speed and direction and the amounts of water collected by the QFC on an hourly basis (see Photo 3).

The analysis of the fog water collection in Anaga began in 1996. At the present time, two QFCs connected to the SEAC model automatic meteorological station (Spanish Society for Cybernetic Applications) are being used. The station records information every ten minutes on all meteorological variables and the fog water collected by the screens. The altitude and the good topographic conditions mean that high daily average quantities of water are collected (Marzol and Valladares 1998) and the quality of the information, over 14 years of continuous data, is proof that this station is a good example for characterizing the fog on the island and for comparing it with other places.

The amounts of water collected by the SFC were too high for the tipping bucket of the automatic meteorological station to function accurately and a smaller sized screen was necessary. Therefore, simultaneous experiments were conducted in both sites with two different sized screens, 1 m^2 (SFC) and ¼ m^2 (QFC), to study the water collection in both sites. The results revealed that the QFC in Boutmezguida collected 8% less water than the SFC per m^2 and the opposite is true in Anaga where the QFC collected 13% more water than the SFC per m^2. A correction factor of 1.086 was applied to the data from Boutmezguida ($SFC\ (l/m^2) = QFC\ (l/m^2) \times 1.086$) and a correction factor of 3.5 was applied to the data from Anaga. For example, in February 2011, the SFC installed in Boutmezguida collected 158.6 l/m^2 of fog water whereas the QFC, 15 metres away, collected 146.1 l/m^2; these quantities show that the SFC collects 7.9% more than the QFC.

Two approaches were used to evaluate the fog water collection in the study area: The first was to define the features of the fog in the SW of Morocco and to reveal its differences to the fog of the Canary Islands. The second approach was to locate, from a geographical point of view, the pressure centres on the days when there was fog in Boutmezguida, (Morocco). This was carried out from 12 June 2006, when the study began, to 30 September 2010. The final step was to decide whether there is a pattern of the meteorological and atmospheric conditions in the Sahara and the Atlantic that explain the seasonal difference in fog water collection between Morocco and the Canaries.

The correlation study of the wind and water uses an hourly scale. The basic problem with the analysis of fog water collection is when occur at the same time as the rain (Marzol 2008). In order to eliminate this over-evaluation, a decision was made to distinguish the total amount of water collected by the screens (fog plus rain) from that coming only from fog, whereby the days with rain were removed from the computation. Furthermore, the automatic meteorological station in Anaga supplies hourly data on the collection of water that only comes from fog. This information is valuable because the screens collect water from fog during many hours when it is rainy, and these hours can be computed.

The methodology used in the synoptic analysis of the days with fog in Morocco is based on dividing the Atlantic space into 80 squares of 5º longitude by 5º latitude delimited between 40ºW and 20ºE longitude and between 25ºN and 70ºN latitude (Fig. 2). This method was used to geo-reference the type of pressure centre – anticyclone or depression – and its pressure (Dorta et al. 1993). The information was taken from the synoptic maps at 12.00 hours GMT from the AEMET (Spanish National Meteorological Agency). Finally, the synoptic data, meteorological

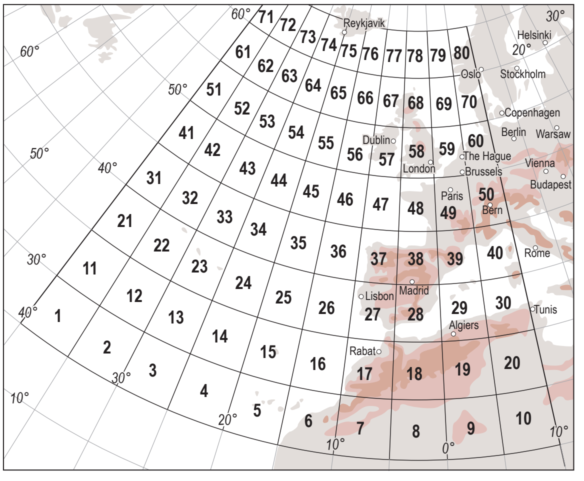

Fig. 2: Template for extracting information from the geographic location of pressure centres on days with fog in Morocco

variables and water collected by the SFCs and QFCs in Boutmezguida and Anaga were used to create a data base.

3 Results

3.1 Cloud frequency in the SW of Morocco and the Canary Islands

In Morocco, there was fog on only 33% of the days (552) out of the total of 1,570 days during the analysis (12 June 2006 to 30 September 2010). There was also fog in Anaga on 89% or 464 of those days. There was rain in Boutmezguida on 66 days and on 145 days in Anaga of the 552 days with fog in Morocco. The "interference" caused by the water from the rain in calculating the collection of water from the screens only amounts to 4% of the total number of analysed days in Morocco and 9% in the Canaries, affecting, above all, the period from October to March. There were 1,239 days with fog in the Canaries (83% of the total) during the study period.

The difference between Morocco and the Canaries does not mean there is less cloud over the islands, but rather that meteorological events do not occur simultaneously in both places. The greater number of days with rain in Anaga, which is 17% of the days in the year, can be added to this first differentiating feature. This fact means that methods of temporal discrimination must be applied to the analysis of the rates of the fog water collection. In spite of the higher frequency of fog in the Canaries, the correlation between the amount of water collected and the monthly number of days with fog is lower than in Morocco (Fig 3).

3.2 The volumes of water collected

The averages of water collected in both places are around 10 litres/m^2 per day, although there are important monthly variations. Table 1 shows the quantity of water collected by the screens: (F_1) is the monthly mean of total water collected (fog + rain), (F_2) the monthly mean of fog water after eliminating the water of days with rain, (F_3) the monthly mean of fog water after eliminating hours with rain, (D_1) the daily mean of total water (fog + rain), (D_2) the daily mean for fog water only, and (D_3) the daily mean of fog water only, but collected on an hourly basis. All daily averages for the month include every day of the month. In the case of Anaga, the difference in the daily collection and the hourly collection of fog water is important (columns 9 and 10 of table 1). When working on an hourly basis, many hours of water are "recovered" as it does not necessarily rain for 24 hours every fog day.

The most outstanding feature between the two sites is the existence of two seasonal patterns in the behaviour of the monthly fog water collected (Fig. 4). The daily averages of figure 4 refer to water coming only from fog, these quantities would be higher if the total of the water collected by the screens was taken into account (see Tab. 1). The pattern in Morocco is characterized by an average of 11.8 l/m^2/day in the seven months from December to June; this amount decreases to 4.3 l/m^2/day from July to November (the values would be 14.5 l/m^2/day and 5.1 l/m^2/day, respectively, if the total of the water collected by the screens was included in the computation). On the other hand, the pattern of the Canaries is defined by the predominance of vertical cloud development during the winter months and, therefore, there is a reduced presence of stratocumulus cloud formation that in turn lowers the amount of water collected

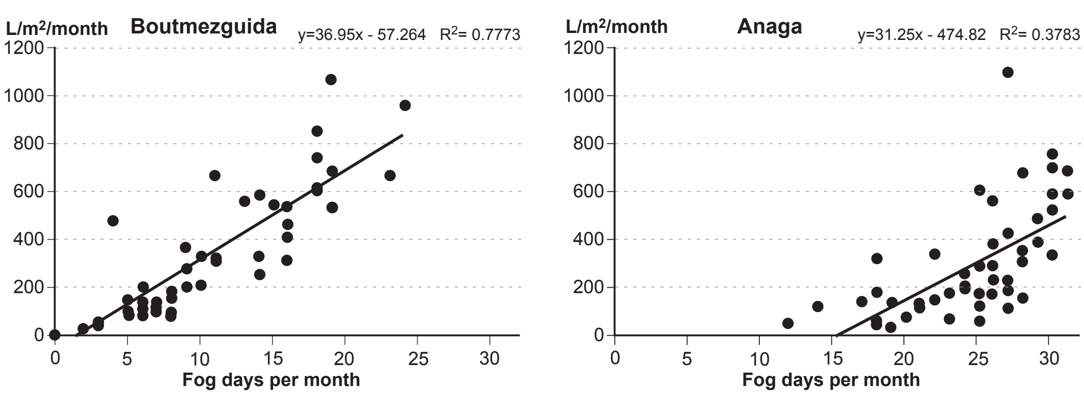

Fig. 3: The relationship between the total amount of water collected and number days with fog per month in Boutmezguida and Anaga (June 2006 to September 2010)

Tab. 1: Monthly (F1,2,3) and daily (D1,2,3) mean amounts of fog water in Boutmezguida (Morocco) and Anaga (Canary Islands) from June 2006 to September 2010 (l/m2). The daily averages include all the days of the month

Month	Boutmezguida (Morocco)				Anaga (Canary Islands)					
	F_1	F_2	D_1	D_2	F_1	F_2	F_3	D_1	D_2	D_3
J	419	277	13.5	8.9	189	35	140	6.1	1.1	4.5
F	364	208	13.0	7.4	207	72	146	7.4	2.6	5.2
M	424	333	13.7	10.7	260	102	194	8.4	3.3	6.3
A	389	389	13.0	13.0	282	162	256	9.4	5.4	8.5
M	410	393	13.2	12.7	288	228	264	9.3	7.4	8.5
J	616	584	20.5	19.5	393	339	388	13.1	11.3	12.9
J	95	48	3.1	1.5	727	694	725	23.4	22.4	23.4
A	561	60	2.0	1.9	641	569	626	20.7	18.3	20.2
S	139	139	4.6	4.6	187	153	179	6.2	5.1	6.0
O	218	160	7.0	5.2	235	113	201	7.6	3.6	6.5
N	270	250	9.0	8.3	174	43	99	5.8	1.4	3.3
D	449	325	14.5	10.5	222	32	141	7.1	1.0	4.6
Mean	3853	3163	10.6	8.7	3803	2541	3361	10.4	6.9	9.2

by the screens so that an average of only 3.4 l/m²/day can be guaranteed from September to May, as opposed to 17.3 l/m²/day from June to August (the values would be 7.5 l/m²/day and 19.1 l/m²/day respectively if the total of the water collected by the screens was included in the computation). The quantity of water collected in the summer is important in ecological terms for the islands, because it provides humidity and water to forest ecosystems when water stress is at its highest (Marzol 2005).

Having meteorological stations connected to the screens available gives one the possibility to study the maximum values of water coming only from fog in different time periods. Thus, in Boutmezguida there are 1060.0 l/m²/month (March 2009), 115.9 l/m²/day (02/07/2010) and 6.7 l/m²/hour (6 hours on 02/07/2010), whereas the quantities in Anaga are 1094.0 l/m²/month (July 2007), 81.4 l/m²/day (02/08/2006) and 9.8 l/m²/ hour (16 hours on 24/07/2007).

3.3 The synoptic weather patterns in the collection of water

There was a surface anticyclone in the eastern Atlantic on 88% of the days with fog in Morocco; on 77% of these days, the centre of the anticyclone was located to the south of the 45° N parallel and its average pressure was 1028 hPa. Another anticyclone, whose frequency was very low (4% of the days with fog) and had a pressure of 1019 hPa, was present in NW Africa. As far as the low pressure centres are concerned, there was one over the Sahara on 48% of the days with fog, with an average pressure of 1007 hPa (Fig. 5).

The fog water collected in July and August in Boutmezguida was only 3.9% of the annual total compared to 40% in Anaga. This water was collected on 7% of the days in these months in Morocco and on 98% of these days in the Canaries. Both places also differed in the daily averages of water collected

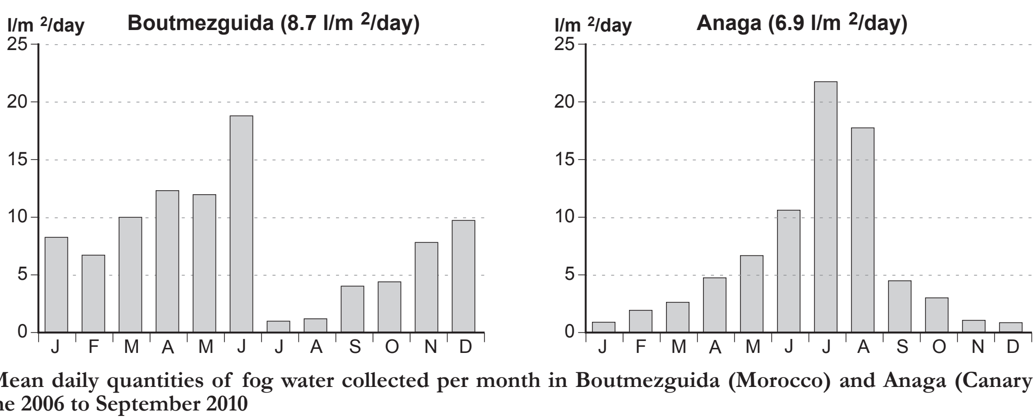

Fig. 4: Mean daily quantities of fog water collected per month in Boutmezguida (Morocco) and Anaga (Canary Islands) from June 2006 to September 2010

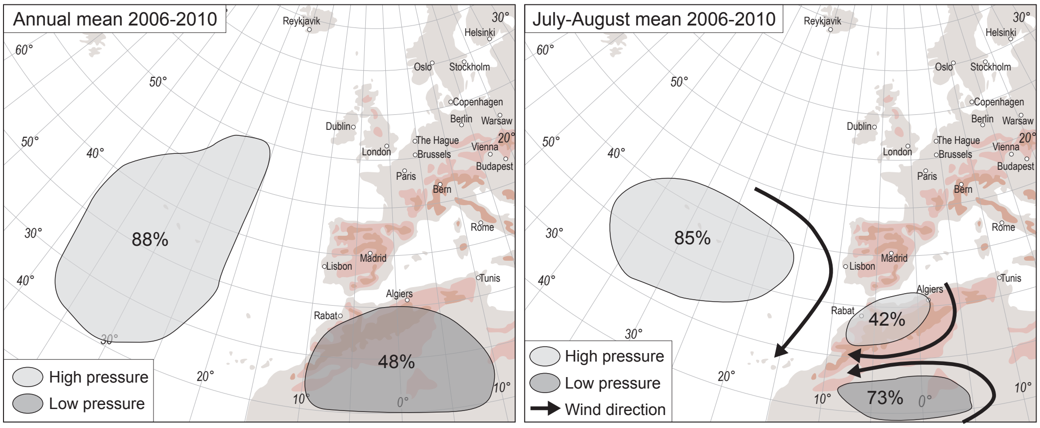

Fig. 5: The location of the pressure centres in the North Atlantic on days with fog and on days without fog (July and August) in Morocco from 2006 to 2010

from the fog, since the daily volume was 1.7 l/m^2 in Boutmezguida and 22.1 l/m^2 in Anaga.

The daily synoptic maps of July and August from 2006 to 2010 were analysed in order to find the reason for the abovementioned difference. The explanation suggested for the differences that exist between Morocco and the Canaries is based on a change in the regional pressure fields during these months, which hinders the fog water collection. The most outstanding features of this change are:

– A lower frequency of the Atlantic anticyclone (85% of days in July and August) but a closer proximity of its centre to the Canaries. The average pressure is slightly lower than that of the rest of the year, which is 1027 hPa (Fig. 5).
– A greater frequency of the thermal depression over the East of the Sahara (73% of days in July and August) which, with an average pressure of 1008 hPa, reduces its area of influence to the South of the Atlas Mountains.
– The appearance of a surface anticyclone of 1015 hPa over the Atlas Mountains on 42% of the days in July and August.

The three pressure centres create a strong barometrical gradient in both months, which give rise to moderate NE trade winds parallel to the Moroccan coastline or from the Atlas Mountains towards the coast. These winds prevent Atlantic cloud from penetrating into Moroccan territory, but favour their path over the Canary archipelago (Fig. 5). The 3 July 2007 exemplifies the atmospheric situation during these two months. The amount of water that was collected only from the fog in Anaga was 99.7 l/m^2, but nonetheless it was a warm, sunny day in Boutmezguida. The surface maps shows how the Atlantic high, in conjunction with the thermal depression over the Sahara and a smaller anticyclone in the North of Algeria, sent hot, dry air towards the African Atlantic coast. This focus of heat above the desert, which is a fog inhibitor, stayed in place up to 1,500 m a.s.l., as can be seen in the image at 850 hPa from the reanalysis of this day (Fig. 6).

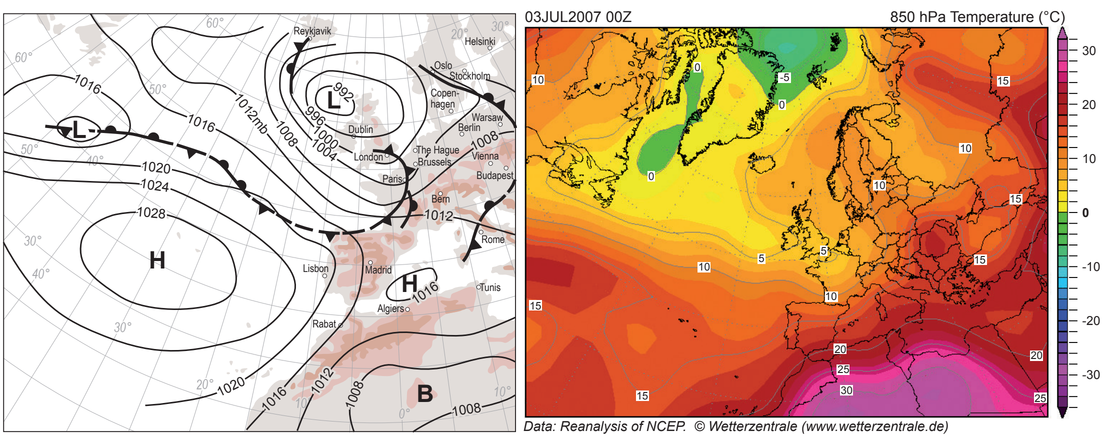

Fig. 6: Surface map and reanalysis map at 850 hPa from 3^{rd} July 2007, an example of a day with fog in Anaga and without fog in Boutmezguida (©AEMET y Wetterzentrale)

Nevertheless, on 12 April 2007 when 20 l/m^2 were collected in Boutmezguida and nothing in Anaga, the atmospheric situation that existed there was of pressure centres in the region of the Canaries and NW Africa that, together with the North winds, facilitated the entry of the cloud across the Moroccan coastline; at the same time, the quantity of the fog water collection increased in Boutmezguida, but declined in Anaga (Fig. 7).

of July and August (5.1 l/m^2/day); and on the other hand, there is the *Canary Pattern* with a marked efficiency in July and August, with an average daily collection of 19.1 l/m^2, which is not the case for the rest of the year when the average is 7.5 l/m^2/day.

The explanation for these differences lies in the disappearance of necessary atmospheric conditions for collecting water – high humidity, low temperatures and a suitable wind speed – in the Sahara Desert

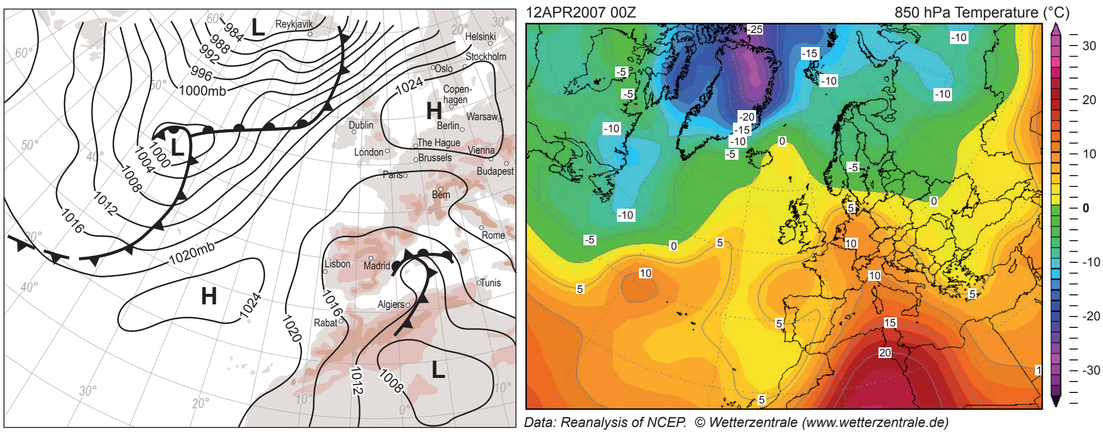

Fig. 7: Surface map and reanalysis map at 850 hPa from 12th April 2007, an example of a day with fog in Boutmezguida and without fog in Anaga (©AEMET y Wetterzentrale)

4 Discussion

The results obtained here support the viability of collecting a part of the liquid content of clouds, as an average of 10 l/m^2/day are assured in both sites, although there are large monthly contrasts. Even though the total amount of water collected is the same, the efficiency of phenomenon is greater in Boutmezguida because the water there can be collected, on average, on ten days a month as opposed to needing twenty-four days in Anaga.

These water averages are higher than those obtained in other areas in South America (Cerro Orara, Peru; La Ventosa in Guatamala; Puluahua, Equador; El Tofo, Chile) and in Africa (Woodbush, South Africa), which several authors consider to be optimal (Schemenauer and Cereceda 1994b; Cereceda and Schemenauer 1996; Olivier and Rautenbach 2007; Marzol and Sánchez 2008).

The differences found between Morocco and the Canaries leads one to think that there are two patterns of fog behaviour in the region of the Canary Islands and NW Africa. On the one hand, there is the *Moroccan Pattern* where the largest amounts of water are collected from December to June, with an average of 14.5 l/m^2/day, but is lower in the months during of summer (table 2 shows the differences between January and August 2010). At this time of year, the heat and drought coupled with weak NNE and NE winds prevent the Atlantic cloud formations from moving onto the continent. Figure 8 shows the dominating wind direction in a dry month, August, and in another month with numerous fog events, such as January 2010, when 350 l/m^2 of water were collected. The predominating continental wind was from the NE in August, whereas the wind oscillated between NNW and NNE in January 2010, which facilitated the arrival of the damp ocean air. At the same time, there are also differences between the hours with collection of fog water and the dry hours in January.

Wind speed is another conditioning factor of water collection. Certain studies report that the best speed is between 3 and 6 m/s, and the correlation declines with higher and lower speeds (Schemenauer et al. 1988; Schemenauer and Joe 1989; Schemenauer and Cereceda 1993a,b, 1994c; Villegas et al. 2008). The available data show that the greatest water collection in Boutmezguida occurs with slightly higher wind speeds: from 6 to 8 m/s. Table 3 shows that 40% of the fog water in January 2010 was collected within the abovementioned wind speed range. Another ex-

Tab. 2: Data taken from the automatic weather station in Boutmezguida in the periods (hours) with and without fog in January and August 2010

	January 2010	August 2010
Total number of hours with data	675 hours	744 hours
Hours with fog	287 h (42%)	23 h (3%)
Hours without fog	388 h (57%)	721 h (97%)
Mean wind speed in hours with fog	6.3 m/s	5.8 m/s
Mean wind speed in hours without fog	2.4 m/s	3.9 m/s
Humidity in hours with fog	97%	92%
Humidity in hours without fog	69%	29%
Mean temperature in hours with fog	7.9°C	14.3°C
Mean temperature in hours without fog	11.0°C	29.3°C
Total amount of fog water collected	350.1 l/m²	23.6 l/m²
Hourly maximum	7.1 l/m²/h (07 h, NNE, with 9.8 m/s)	2.5 l/m²/h (06 h, NNW, with 6.3 m/s)

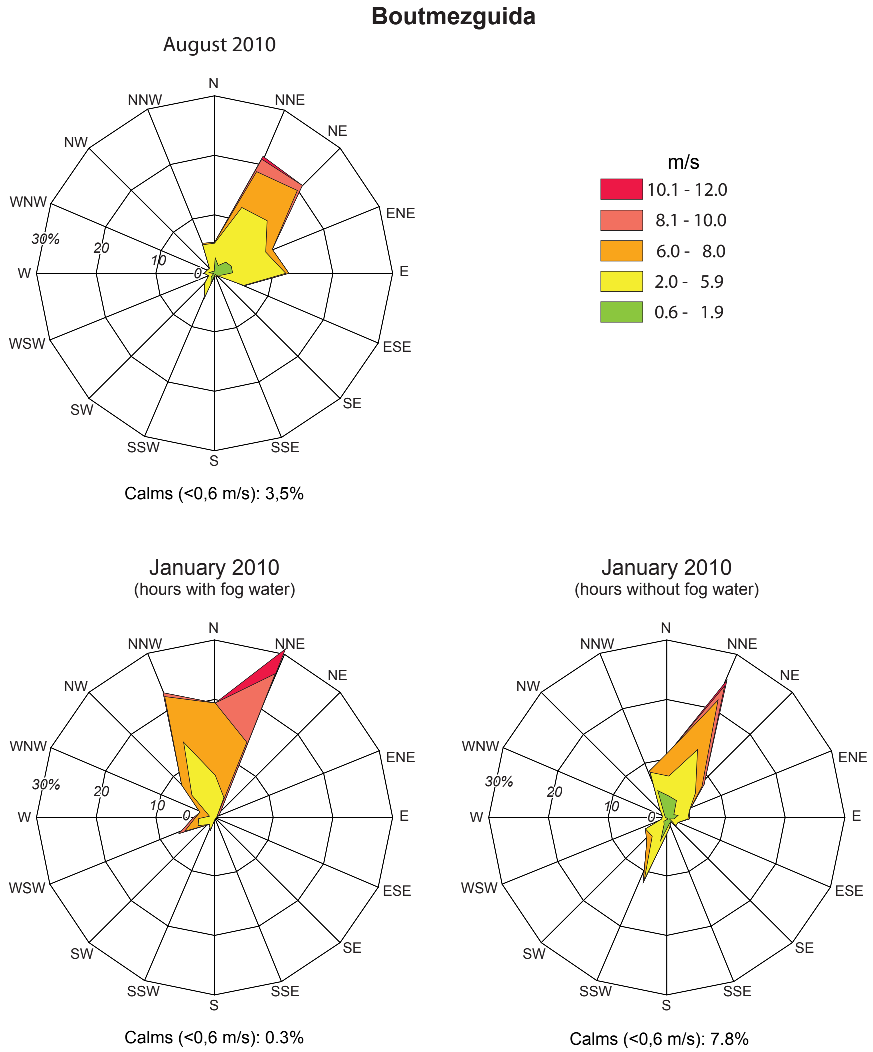

Fig. 8: Wind roses from August 2010 (month without fog water) and January (month with fog water) in Boutmezguida, Morocco. Wind roses for January show the differences between the hours when fog water was collected and the hours without fog water

Tab. 3: The percentage of fog water collected as a function of wind speed category in Boutmezguida in January 2010

m/s	Total of hours	%	Total of water l/m^2	%
< 0.6	34	5	0.6	0.2
0.6 – 1.9	109	16	0.9	0.2
2.0 – 5.9	285	42	81.7	23.3
6.0 – 8.0	161	24	139.0	39.7
8.1 – 10.0	70	10	96.9	27.7
10.1 – 12.0	17	3	31.1	8.9
Total	676		350.1	

ample confirming the importance of the wind speed in the collection of water and in defining the two patterns can be found by looking at what happened in the wet month of January 2010, when 57% of the hours were predominated by NNW and NNE winds and 70% of the water was collected when the winds came from these directions (Tab. 4).

5 Conclusion

The comparison of the fog characteristics on the Atlantic coast of Morocco and in the Canary Archipelago reveals the existence of two specific patterns. These two patterns are a response to the differing organization of pressure fields in the Atlantic and North African region. Therefore:

Tab. 4: Relationship between wind direction and the quantity of fog water collected in January 2010 in Boutmezguida, Morocco

Direction	Number of hours	%	Amount of water (l/m^2)	%
N	100	15	39,9	11
NNE	187	28	170,2	49
NE	35	5	0,6	0
ENE	14	2	0	0
E	13	2	0	0
ESE	6	1	0	0
SE	6	1	0	0
SSE	2	0	0	0
S	6	1	0	0
SSW	51	8	0,8	0
SW	25	4	0,3	0
WSW	36	5	16,2	5
W	16	2	14,5	4
WNW	13	2	14,8	4
NW	32	5	33,1	9
NNW	100	15	59,7	17
CALM	34	15	0	0
Total	674		350.	

– In the *Moroccan pattern*, large amounts of water can be collected during the seven months of the year between December and June, as for example, when nearly 15 l/m^2/day of water can be collected on average, whereas the water collection is three times lower in the summer.
– The *Canary pattern* behaves inversely to the Moroccan model and is highly efficient from June to August when the average quantity of water collected is 19 l/m^2/day, but this average is three times lower during the rest of the year.

The explanation for this difference lies in the change of the atmospheric conditions, basically wind direction, in the summer in the east of Morocco. The dry winds from the Sahara impede the Atlantic clouds from entering the continent.

The average amounts of water collected from fog confirm the viability of collecting it in SW Morocco and a favourable diagnosis can be made for using this collection system. The access problems of the local population to water, where consumption is below the minimum level laid down by the WHO (2003) and UNESCO (2006), means that this system is a sustainable and suitable solution for use in dispersed rural communities, as it will provide these communities with meaningful social, economic and health benefits, especially for the women and children.

The resource of fog water is assured on one out of every three days a year, it is abundant in the winter months, but almost inexistent in July and August, which is why it will be necessary to include this important feature in supply forecasts. Basic domestic water requirements can be met by the installation of LFCs near the communities with the greatest supply problems, and by the provision of water storage tanks as well as by a water treatment programme to make it drinkable. Another way to take advantage of this method of obtaining water is to put a container below the *argan* trees to collect the water that continuously drips from their branches, which could then be put into troughs for the livestock.

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