Anuário do Instituto de Geociências - UFRJ
www.anuario.igeo.ufrj.br

Wind Pattern Change Along a Period of Coastal Occurrence Variation of a Stinging Medusa on a SW Atlantic Beach

Mudança no Padrão dos Ventos ao Longo de um Período de Variação na Ocorrência Costeira de uma Medusa Urticante em uma Praia do Atlântico SW

Andrea Soledad Brendel[1,2,3]; María Sofía Dutto[1];
María Clara Menéndez[1]; María Andrea Huamantinco Cisneros[1,2] & María Cintia Piccolo[1,2]

[1]Universidad Nacional del Sur, Instituto Argentino de Oceanografía,
Camino La Carrindanga, km 7, Edificio E1, C.C 804, Bahía Blanca, Argentina.
[2]Universidad Nacional del Sur, Departamento de Geografía y Turismo, 12 de Octubre, 1198, 4° piso, Bahía Blanca, Argentina.
[3]Universidad Nacional del Sur, Departamento de Agronomía, San Andrés, 800, Bahía Blanca, Argentina.
E-mails: andreabrendeluns@gmail.com; msofia.dutto@gmail.com ;
mcmenendez@gmail.com; mandreahc80@gmail.com; mcpiccol@gmail.com

Recebido em: 13/10/2017 Aprovado em: 20/11/2017
DOI: http://dx.doi.org/10.11137/2017_3_303_315

Abstract

Monte Hermoso (SW Atlantic, Argentina) is a coastal ecosystem highly modulated by wind forcing. Offshore winds have historically played a leading role in the tourist influx as they are associated with the occurrence of the endemic stinging medusa *Olindias sambaquiensis*. This species is closely related to warm summers but it could be favored by low temperatures in previous winters. Since summer 2013, a change in the wind pattern was locally perceived coincidently with the absence of the medusa in coastal waters. This work aimed at analyzing if wind pattern and sea surface temperature (SST) showed a measurable change along 2008-2015 and evaluating if this change can be associated to the observed variations in the occurrence pattern of *O. sambaquiensis*. Winds and SST data were analyzed in periods of high (2008-2012) and low (2013-2015) medusae occurrence, based on media and own observations. A significant change in the wind pattern in Monte Hermoso was detected. Wind speed decreased from 6.3 m s^{-1} in 2008 to 2.4 m s^{-1} in 2015 and calms and light winds increased by more than 44.2 and 7.5 %, respectively. This change implied an impediment of coastal upwelling, which is the physical process by which medusae reach the coast, and is associated with persistent (10 h or more) WNW to ENE winds blowing at $\geq$ 3.3 m s^{-1}. Accordingly, in summer 2008 (period of high medusae occurrence), 45 coastal upwelling-days were detected in contrast to only 8 days in summer 2015 (period of absence of medusae). Also, positive SST anomalies were found over the 8-yr period, suggesting an increasing trend of 0.4 °C. Higher temperatures than normal during recent winters probably affect negatively the polyp reproduction. Our results demonstrate an environmental change in the ecosystem of Monte Hermoso and may explain, in part, the low occurrence of *O. sambaquiensis* in recent summers. The knowledge of the factors that regulate the occurrence of *O. sambaquiensis* is fundamental for developing a coastal management plan and/or for determining the first adaptation strategies.
Keywords: offshore winds; Sea Surface Temperature (SST) anomalies; coastal ecosystem; *Olindias sambaquiensis*; Southwestern Atlantic Ocean

Resumo

Monte Hermoso (SW Atlantic, Argentina) é um ecossistema costeiro altamente modulado pelo forçamento do vento. Os ventos marais têm historicamente desempenhado um papel de liderança no influxo turístico, uma vez que estão associados à ocorrência da medusa endêmica *Olindias sambaquiensis*. Esta espécie está intimamente relacionada aos verões quentes, mas pode ser favorecida por baixas temperaturas em invernos anteriores. Desde o verão de 2013, uma mudança no padrão de vento foi percebida localmente coincidentemente com a ausência da medusa nas águas costeiras. Este trabalho teve como objetivo analisar se o padrão de vento e a temperatura da superfície do mar (SST) mostraram uma alteração mensurável ao longo de 2008-2015 e avaliando se essa alteração pode ser associada às variações observadas no padrão de ocorrência de *O. sambaquiensis*. Os dados de ventos e SST foram analisados em períodos de alta (2008-2012) e baixa (2013-2015), baseada em mídia e observações próprias. Uma mudança significativa no padrão de vento em Monte Hermoso foi detectada. A velocidade do vento diminuiu de 6,3 m s^{-1} em 2008 para 2,4 m s^{-1} em 2015 e a acalma e os ventos leves aumentaram em mais de 44,2 e 7,5%, respectivamente. Essa mudança implicou um impedimento de afloramento costeiro, que é o processo físico pelo qual medusae atinge a costa, e está associado a persistentes (10 h ou mais) WNW para os ventos ENE soprando a $\geq$ 3,3 m s^{-1}. Conseqüentemente, no verão de 2008 (período de alta ocorrência de medusae), 45 dias de afloramento costeiros foram detectados em contraste com apenas 8 dias no verão de 2015 (período de ausência de medusae). Além disso, foram observadas anomalias SST positivas ao longo do período de 8 anos, sugerindo uma tendência crescente de 0,4 ° C. Temperaturas mais altas do que o normal durante os invernos recentes provavelmente afetam negativamente a reprodução do pólipo. Nossos resultados demonstram uma mudança ambiental no ecossistema de Monte Hermoso e podem explicar, em parte, a baixa ocorrência de *O. sambaquiensis* nos verões recentes. O conhecimento dos fatores que regulam a ocorrência de *O. sambaquiensis* é fundamental para o desenvolvimento de um plano de manejo costeiro e / ou para a determinação das primeiras estratégias de adaptação.
Palavras-chave: ventos marais; Anomalias da temperatura da superfície do mar (SST); ecossistema costeiro; *Olindias sambaquiensis*;

Oceano Atlântico Sudoeste

1 Introduction

Coastal environments are dominated by complex interactions among atmospheric, terrestrial and marine factors. Circulation in neritic waters tends to be more active and complicated than in the open sea due to the effects of bottom and shoreline topography (Mc Connaughey, 1982; Barua, 2005) and meteorological phenomena (Ingle, 1999). For instance, offshore winds tend to drive surface waters seaward and cause intermediate depth water to move shoreward and upwell near the coast. Thus, on coasts, winds usually account for seasonal dynamics as well as much of the daily and between-day variability in water circulation, nutrients input and the occurrence, abundance and spatial distribution of marine biota (*e.g.* Villate, 1994, 1997; Gómez Erache *et al.*, 2000). This may have an impact in many economic activities, including coastal management and fishing (Sousa *et al.*, 2012).

Despite of the importance of local winds on the spatio-temporal distribution of organisms, in particular of planktonic ones, there are few studies considering this topic in the literature of coastal waters. Within zooplankton, gelatinous species like medusae are greatly affected by wind-driven events and/or hydrodynamic processes (Arai, 1992; Graham *et al.*, 2001; Purcell & Decker, 2005). Dense aggregations of medusae frequently occur in the surface waters along coastal margins, influenced by the direction and energy of prevailing winds and surface currents (Graham *et al.*, 2001). Variation in medusae abundance can be a function of wind-driven circulation being wind dynamics more influential to jellyfish encounters with humans than any other abiotic variable (Decker *et al.*, 2007; Kaneshiro-Pineiro & Kimmel, 2015). This is particularly important in tourist coastal areas where environmental information for the prediction of stinging species is employed to prevent harmful encounters (Kaneshiro-Pineiro & Kimmel, 2015; Keesing *et al.*, 2015). Temperature is another factor that influences blooming potential in medusae (Arai, 1992; Purcell, 2005; Schiariti *et al.*, 2014), so it should be considered to understand variations in the dynamic of their populations.

The coastal area located on the northern Argentine continental shelf at 38°- 42° S comprises highly relevant ecosystems from biological, economical and touristic viewpoints (Hoffmeyer *et al.*, 2009; Auad & Martos, 2012). This area is particularly responsive to atmospheric conditions due to its shallow depths and its extreme breadth (Piccolo, 1998; Lucas *et al.*, 2005). Local inputs, tidal currents, seasonal thermal cycles and prevailing winds play crucial roles in influencing the inner shelf dynamic and the biological communities living in it (Lucas *et al.*, 2005; Hoffmeyer *et al.*, 2009; Auad & Martos, 2012). Furthermore, some biological patterns in the area are closely connected and forced by local wind stresses (Auad & Martos, 2012; Menéndez *et al.*, 2012; Delgado *et al.*, 2015).

One of the most enigmatic cases in the region of a biological pattern supposedly driven by winds takes place in Monte Hermoso and involves a stinging medusa species. Monte Hermoso is a touristic sandy beach mainly modulated by winds and tidal forcing (Martos & Piccolo, 1988; Delgado *et al.*, 2012). Prevailing winds are from the N-NNW-NW directions and produce, particularly in summer, increases in the air temperature, fluctuations of the atmospheric pressure and environmental dryness (Delgado *et al.*, 2012). The presence of the stinging medusa *Olindias sambaquiensis* in coastal waters during summer is a determining factor in the tourism flow to Monte Hermoso, and local people associate its occurrence to the influence of persistent and intense N winds (offshore direction) (Figure 1). Varela (1982) and Mianzan & Zamponi (1988) studied this relationship and found higher probabilities of medusae encounters under persistent (18 to 24 h.) and intense (3.3 to 4.2 m s^{-1}) N winds. This result was based on the coastline orientation (E to W) which allows that N winds cause coastal upwellings removing surface waters and producing the emergence of the bottom layer, promoting that medusae inhabiting in it reach the coast (Mianzan & Zamponi, 1988). Extremely high abundances has been commonly reported in the region (Mianzan *et al.*, 2001; Chiaverano *et al.*, 2004) but since the summer 2013, medusae of *O. sambaquiensis* have not been observed in the coastal waters of Monte Hermoso and surrounding areas (Dutto *et al.*, 2017). Also, a change in the local wind pattern has been perceived by local visitors and reported by media but it has not been studied until now (Figure 2). Thus, the aim of this work was to analyze if wind pattern showed a measurable change in terms of predominance (h d^{-1}), persistence (consecutive h d^{-1}) and speed (m s^{-1}) between 2008 and 2015, and to compare within this period, the wind pattern during summers in which medusae were locally reported with those summers in which medusae were absent according to media reports and own data. Complementary, the Sea Surface Temperature (SST) pattern was also analyzed during the study period in order to look for variations that help to explain the reported changes in the medusa occurrence.

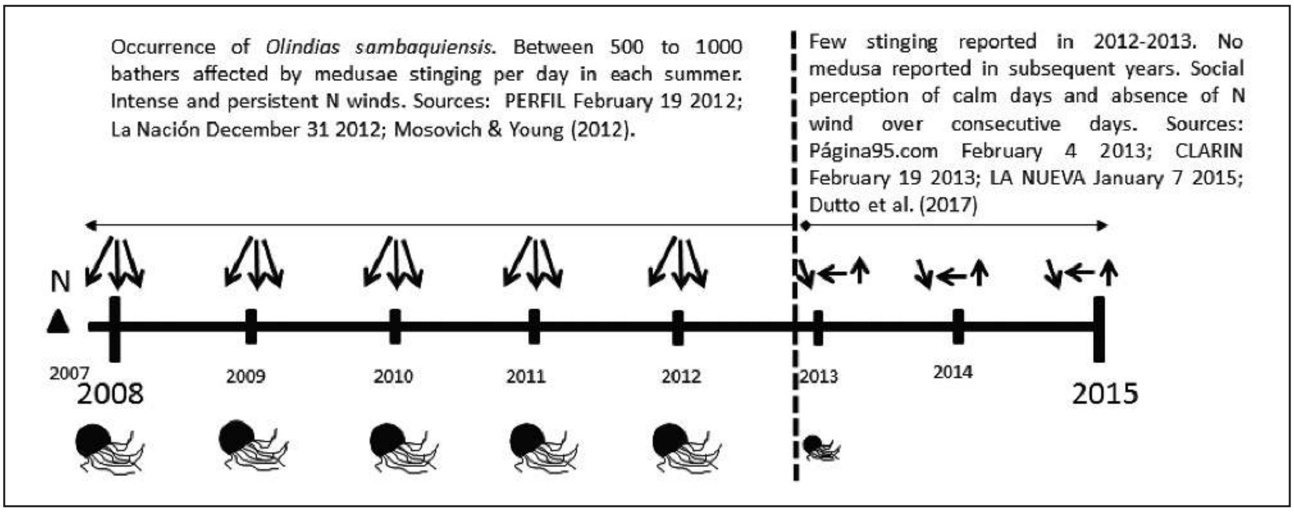
2 Methods

2.1 Study Area

The southern coast of Buenos Aires Province, Argentina, is an open and straight E-W orientated shoreline. Monte Hermoso (38º 59' S-61º 41' W, Figure 3), located on this coast, is a wide dissipative sandy beach of 32 km-long characterized by a low slope and backed by extensive sand dunes (Caló *et al.*, 2005; Huamantinco Cisneros & Piccolo, 2011; Delgado *et al.*, 2012). The area shows a mesotidal regime (2.44–3.61 m) with semidiurnal tidal cycles (Delgado *et al.*, 2012; Servicio de Hidrografía Naval, 2016) and is characterized by temperate (15 °C), high saline (35), and turbid (37 NTU) waters, with pronounced seasonal variability and homogeneity of the water column all year round (Delgado *et al.*, 2016). The waters of Monte Hermoso are highly influenced by the plume of the Bahía Blanca Estuary (38°45'-30°40'S; 61°45'-62°30'W, Figure 3) mainly by sediments input (Delgado *et al.*, 2016). Moreover, the composition of benthic and planktonic communites of Monte Hermoso may reflect the estuarine influence (Carcedo *et al.*, 2015; Menéndez *et al.*, 2016).

The region has a temperate climate characterized by warm summers, cold winters, moderate

Figure 1
(A) *Olindias sambaquiensis* swarm washed ashore on Monte Hermoso beach in November 2008. Note the direction of the wind, blowing perpendicularly to the coastline (offshore direction) (photography courtesy of Paula Costilla);
(B) Specimen of *O. sambaquiensis* (photography courtesy of Alvaro Migotto, http://cifonauta.cebimar.usp.br/)



Occurrence of *Olindias sambaquiensis*. Between 500 to 1000 bathers affected by medusae stinging per day in each summer. Intense and persistent N winds. Sources: PERFIL February 19 2012; La Nación December 31 2012; Mosovich & Young (2012).

Few stinging reported in 2012-2013. No medusa reported in subsequent years. Social perception of calm days and absence of N wind over consecutive days. Sources: Página95.com February 4 2013; CLARIN February 19 2013; LA NUEVA January 7 2015; Dutto et al. (2017)

Figure 2 Summary of the reported occurrence pattern of the medusa *O. sambaquiensis* during the summers of the period 2008-2015 in Monte Hermoso, Argentina; speed and persistence associated to perceived local winds (mentioned in media articles) are represented by direction and length of the arrows.

springs and autumns, and the influence of diverse air masses that gives variability in its weather condition (Delgado *et al.*, 2012; Huamantinco Cisneros, 2012). Mean temperatures vary between 8 (winter) and 21.4 °C (summer), evidencing a marked seasonality (Huamantinco Cisneros, 2012). Prevailing winds throughout the year are from the N, NW and NNW directions with mean speed of 4 m s^{-1} while S, SE, SSE, SW and SSW winds are more intense (mean speed of 6.4 m s^{-1}) and less frequent (Lucas *et al.*, 2005; Delgado *et al.*, 2012; Huamantinco Cisneros, 2012).

Monte Hermoso beach is associated to the homonymous coastal city. Tourism and secondly artisanal fishery, represent its main economic activities, therefore, there is an intense use of marine and coastal resources (Vaquero *et al.*, 2007; Rojas *et al.*, 2015). Monte Hermoso has evolved into a tourist center which shows the greatest population growth and expansion of the region due to it is one of the most selected tourist destinations of Argentina (Vaquero *et al.*, 2007). During summers its population increases by more than 60,000 people (up to 1000 %) (Rojas *et al.*, 2015).

2.2 Data Collection and Analysis

Wind data (speed and direction) for the period 2008-2015 were obtained from a meteorological monitoring station located in Monte Hermoso. The meteorological station integrates a coastal environmental monitoring stations network and is available on its website (EMAC, Estación de Monitoreo Ambiental Costero, http://emac.criba.edu.ar). EMAC provides, since 2007, continuous measurements of meteorological variables including air temperature, relative humidity, atmospheric pressure, wind speed, wind direction and solar radiation. All sensors were developed at the Instituto Argentino de Oceanografía and record measurements at 5-minute intervals.

SST data were obtained from the National Center for Environmental Prediction-National Center for Atmospheric Research (NCEP/NCAR) reanalysis data. NCEP/NCAR isa consistent long period data set and is one of the few available for oceanic model forcing (see Kalnay *et al.*, 1996). It has been widely used over the Southern Hemisphere including several studies performed in the Argentine platform (Auad & Martos, 2012; Simionato *et al.*,

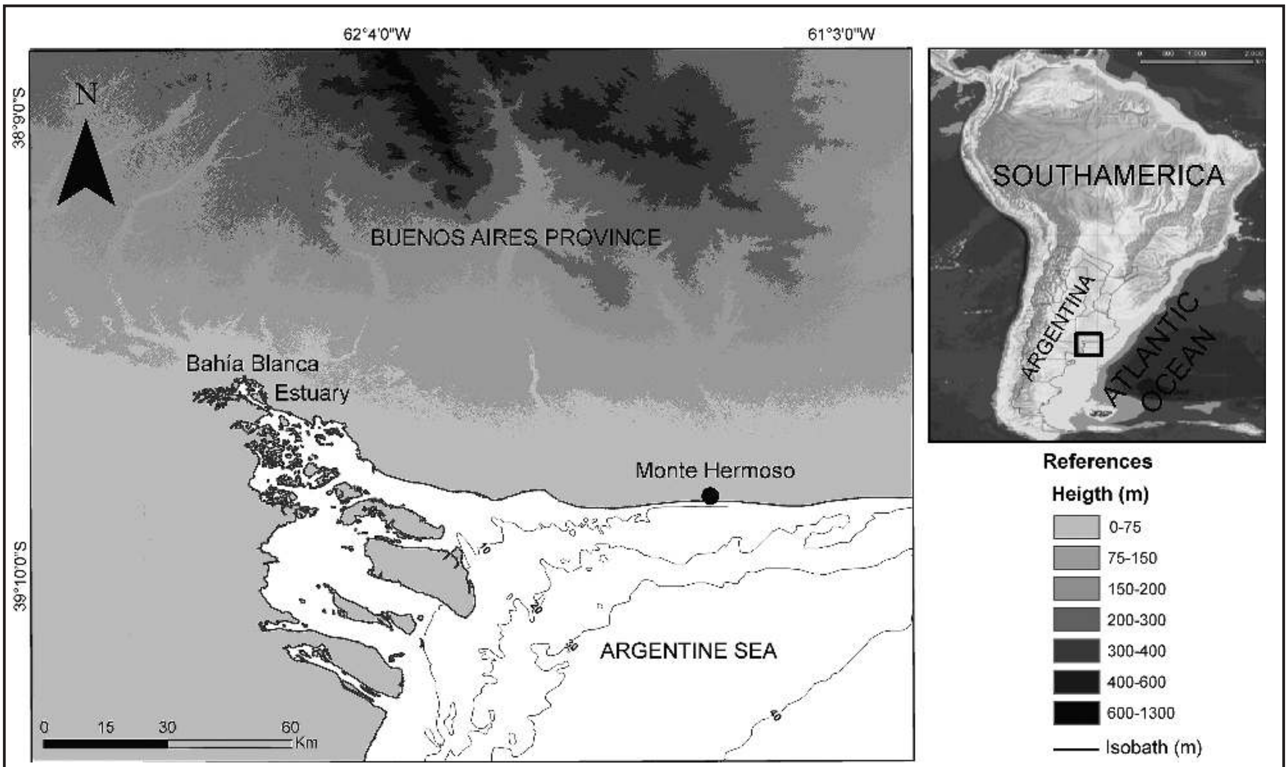


Figure 3 Location of Monte Hermoso (study area) in the southern region of Buenos Aires province (Argentina).

2005). The discussion on the quality of its use in the Southern Hemisphere can be found in Garreaud & Battisti (1999) and Simmonds & Keay (2009). The data provided for the NCEP/NCAR are within the range of data measured *in situ* during 2008-2010 (Huamantinco Cisneros, 2012; Menéndez *et al*., 2016).

Wind and sea temperature analyses were firstly performed considering the whole 8-yr period (2008-2015). Thus, to visualize the wind pattern, the direction and speed of winds along with the air temperature were plotted throughout 2008-2015. Winds were also classified according to Beaufort Scale as calm (<0.5 m s^{-1}), light winds (0.5-3.3 m s^{-1}), moderate winds (3.3-10.8 m s^{-1}) and strong winds (>10.8 m s^{-1}), and the percentage of each Beaufort category was calculated monthly and plotted over the period. To analyze SST, monthly temperature means from NCEP/NCAR Reanalysis of the period 2008-2015 on a 2.5 x 2.5 latitude–longitude grid were used as the primary data. Annual and monthly SST means of the period 1948-2015 were then employed to estimate monthly and annual anomalies for the period 2008-2015.

The second time-scale focused on summers within the period 2008-2015, given that medusae typically show strong seasonality displaying maximum population values on the warmest months. Therefore, the direction and speed of winds were plotted for each summer, and the frequency of occurrence and the mean speed of winds were associated to each plot. To compare the wind patterns between contrasting periods in relation to medusae occurrence, two summers were chosen based on local media and published biological data (Figure 2). Thus, December 2007, January and February 2008, henceforth summer 2008, was chosen as a representative period of high medusae occurrence, while December 2014, January and February 2015, henceforth summer 2015, was considered as a representative one of absence of medusae. Medusae-associated winds (WNW-ENE) (Mianzan and Zamponi, 1988) were selected and predominance (h d^{-1}) and persistence (consecutive h d^{-1}) were estimated and evaluated over those summers. The number of days of winds associated to medusae occurrence (WNW-ENE winds blowing for 10 h or more, and speed ≥ 3.3 m s^{-1}, Mianzan & Zamponi, 1988) were compared between summers 2008 and 2015.

2.3 Statistical Analysis

Wind variables (speed, predominance and persistence) and the number of days of winds associated to medusae occurrence were compared between summers 2008 and 2015 applying Mann-Whitney tests given that normality was not assumed even after data transformation. Principal Component Analysis (PCA) using Spearman's rank correlation matrix was used to arrange and visualize the data, and to detect relationships among variables (Beaufort categories of winds and SST). The first two principal components (PC1 and PC2) were retained given that they explained a meaningful part of the total variation. Plotted variables showed a reconstruction percentage >50 % in the two-dimensional plot.

3 Results

3.1 Wind Speed Throughout the Whole 8-yr Period (2008-2015)

The wind speed showed a decreasing trend over the period 2008-2015 (6.3 m s^{-1} in 2008, 4.4 m s^{-1} in 2011 and 2.4 m s^{-1} in 2015, Figure 4A), and it seemed to follow a seasonal variation: N winds seemed to be more frequent in summers, while S winds seemed to dominate during winters (Figure 4A). A change in wind speed was detected through the study period and this was clearly observed by the Beaufort categories (Figure 4B). Calms increased from 1.3 % in 2008 to 45.5 % in 2015, while light winds were represented by 21 % in 2008 and increased to 28.5 % in 2015. Oppositely, moderate winds decreased from 67.3 % in 2008 to 22.8 % in 2015, and strong winds were 10.4 % in 2008 and shifted to 3.2 % in 2015 (Figure 4B). During 2008-2012 (period of high medusae occurrence), calms were consistently below the mean of the study period (12.7 %). In 2008, calms represented 1.3 % of the total winds, while in 2009 they increased to 4.1%. Similar values were found in 2010 (9.2 %), 2011 (9 %) and 2012 (10 %). During 2013, calms accounted for 9.5 %. Major percentages of calms happened during 2014 and 2015, showing values of 13.9 and 45.5%, respectively. Light winds averaged 32.7 % across 2008-2015. They were consistently above the general mean (36.2 % in 2010, 36 % in 2011, 43 % in 2012, 36.1 % in 2013, 37.6 % in 2014) with the exception of 2015 which showed lower values (28.5 %). The mean of moderate winds was 49 %, decreasing from 2008 to 2015 and showing their lowest value in 2015 (22.8 %, Figure 4B). Strong winds showed a mean of 5.6 % and similarly to moderate ones, they decreased from 2008 (10.4 %) to 2015 (3.2 %), being the latter the lowest value found over the entire study period (Figure 4B).

3.2 Sea Surface Temperature Anomalies Throughout the Whole 8-yr Period (2008-2015)

SST averaged 14.6 °C during 2008-2015. Annual anomalies were positive and the highest value was in 2015 (0.6 °C) followed by the anomalies found in 2009 and 2014 (0.5 °C in both years) (Figure 5). From 2008 to 2013, monthly SST anomalies were mainly positive but negative ones were detected in 33 % of cases especially during cold months (Figure 6). Positive anomalies were consistently found in 2014. In 2015, positive anomalies were found from March to August, being the largest period of consecutive positive SST anomalies higher than 1.3 °C (Figure 6). Negative anomalies were only found in January and September in 2015 (Figure 6). The highest positive anomalies were detected in March 2009 and March and May 2015 (1.8 °C in all cases), and the negatives ones were observed in November 2009 and March 2013 (-1.5 and -1.4 °C, respectively) (Figure 6).

3.3 Principal Component Analysis (PCA): Relationships Among Variables

The first two components explained respectively 53.8 and 17.27 % of the total variance (Figure 7). The first axis (PC1) was positively correlated to moderate and strong winds (contributions of 29.76 and 19.32 % to PC1, respectively), and negatively to calms and light winds (24.6 and 18.1 %, respectively) (Figure 7). The second axis (PC2) was

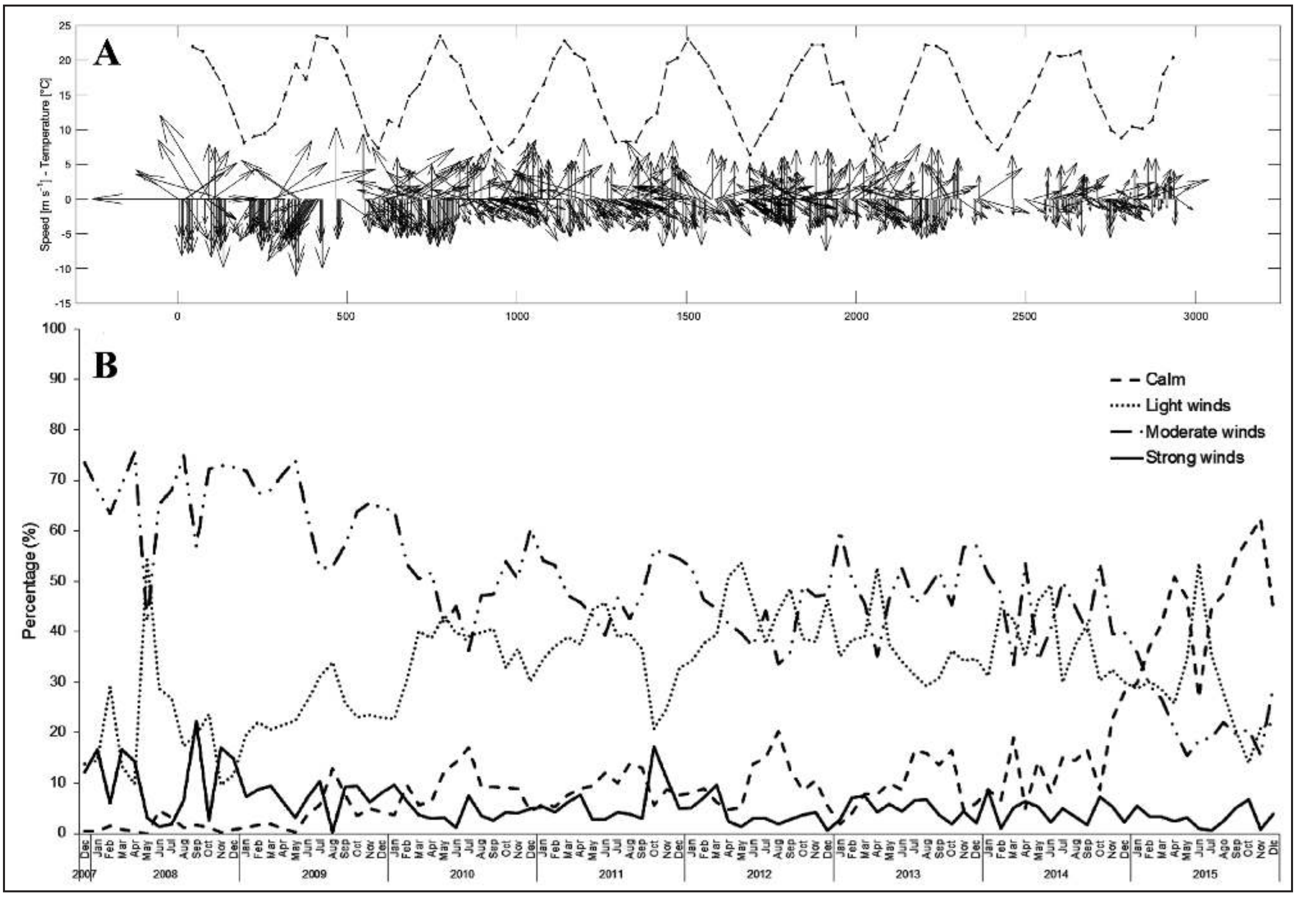


Figure 4 (A) Wind direction and speed during the study period (2008-2015). Wind direction is indicated according to the meteorological convention (*i.e.* the direction from which the wind is blowing) and speed is represented by the length of the arrows. (B) Monthly occurrence (%) of wind categories during the study period. Winds were classified as calms, light, moderate and strong winds according to the Beaufort scale.

positively correlated to SST (contribution of 63.2 %). Thus, the PC1 evidenced a clear “wind speed gradient”, positioning the sampling dates of 2008 on the right side (positive axis) of the plot associated to Moderate/Strong winds whereas those of 2015 were mainly located on the left side (negative axis) of the plot according to Calms/Light winds (Figure 7). Remaining sampling dates were positioned in the middle of the plot following a seasonal ordination on PC2 (Figure 7).

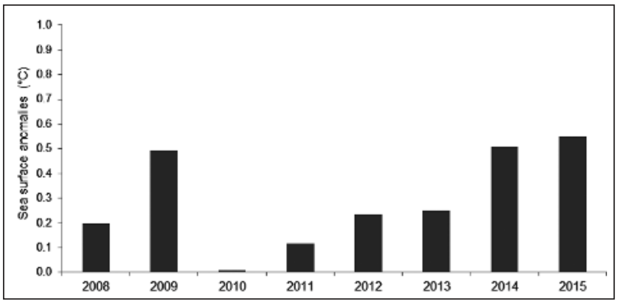


Figure 5 Annual SST anomalies during the period 2008-2015.

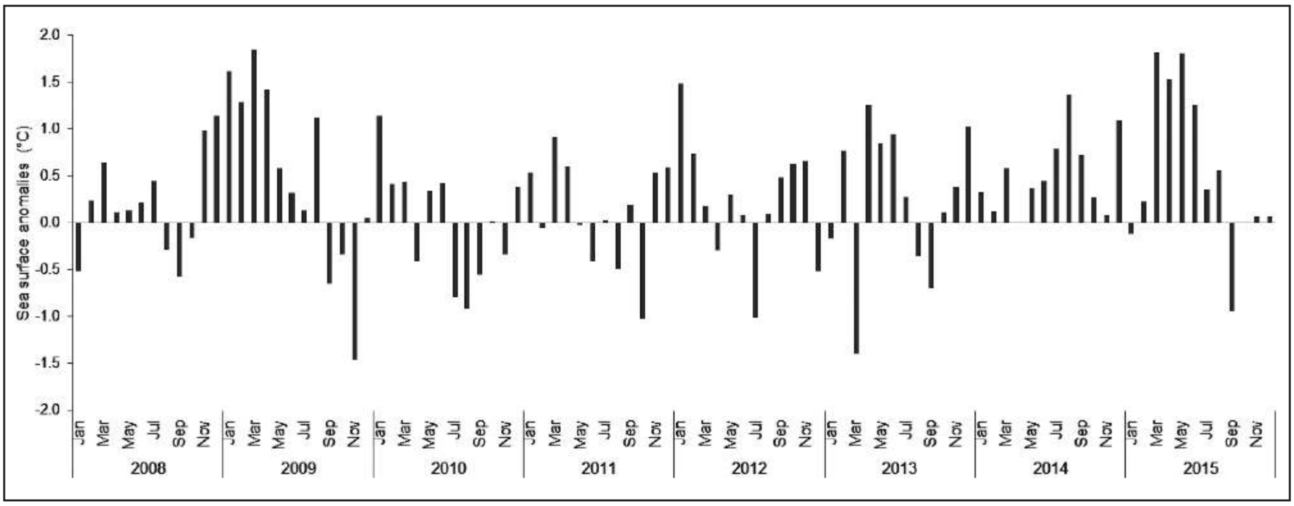


Figure 6 Monthly SST anomalies during the period 2008-2015.

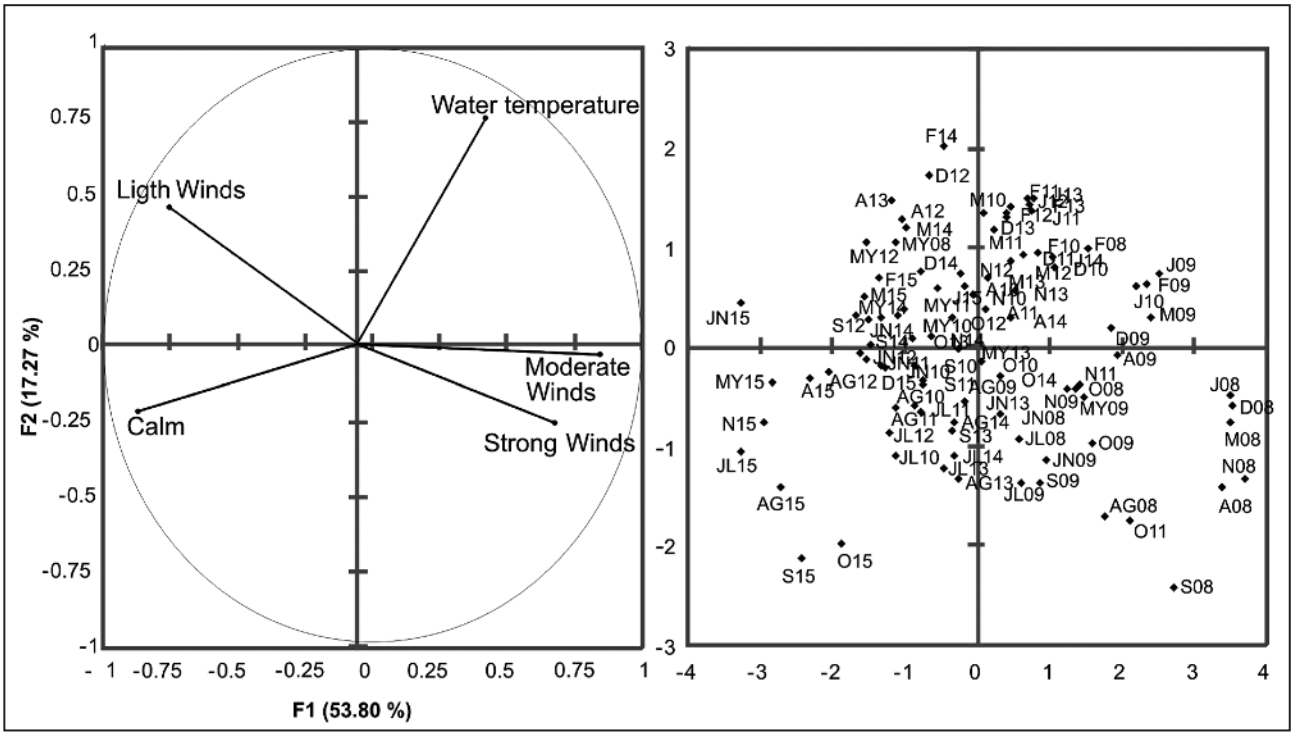


Figure 7 Results of the Principal Components Analysis (PCA) considering environmental variables (sea surface temperature -SST-, and winds following Beaufort scale -calms, light, moderate and strong winds-) (A), and sampling dates (B).

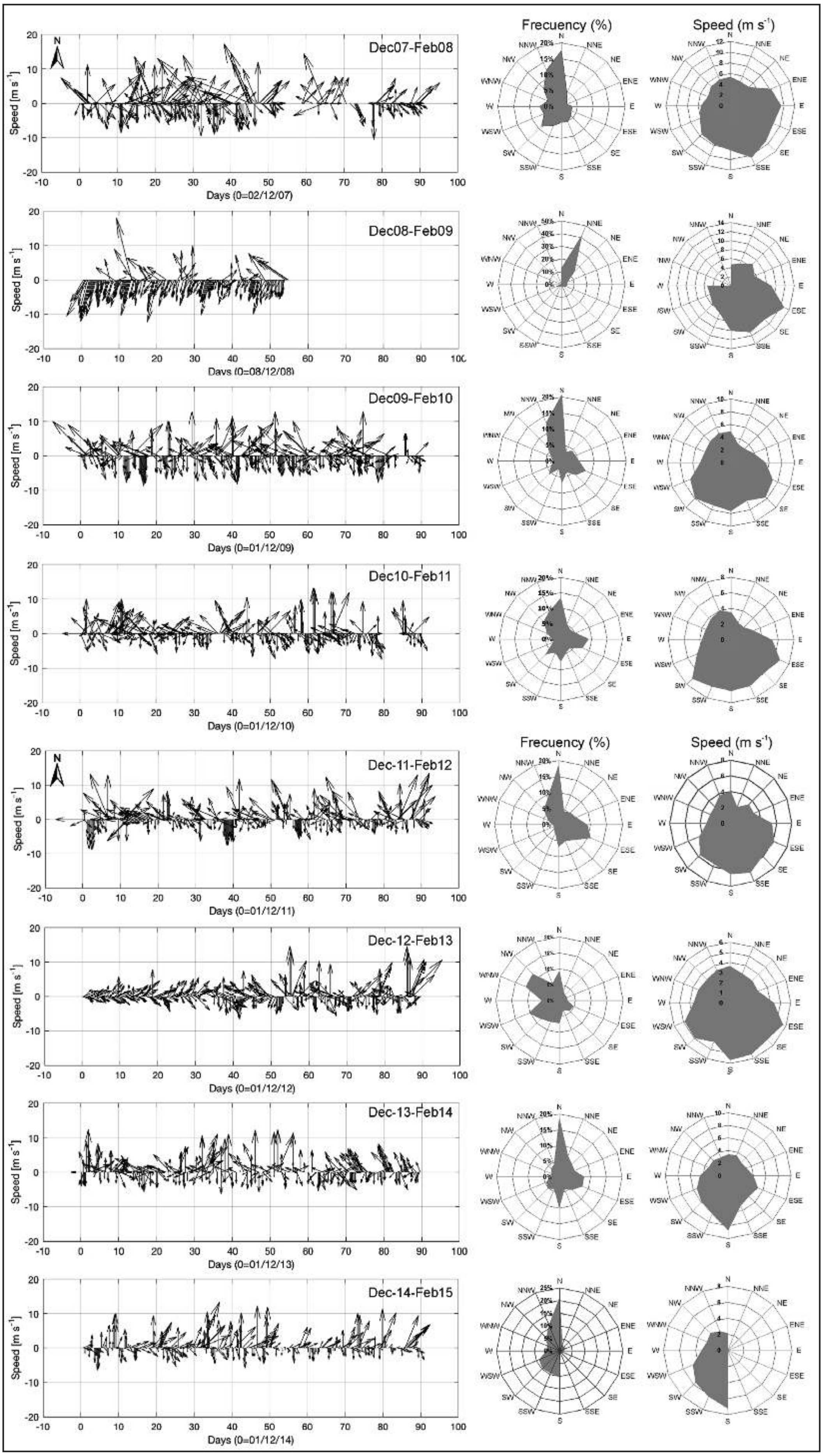


Figure 8 Wind direction and speed during summer (December, January, and February) 2008 and 2015 in Monte Hermoso. Wind direction is indicated according to the meteorological convention (*i.e.* the direction from which the wind is blowing) and speed is represented by the length of the arrows. Wind rose plots next to each vector plot show frequency of wind occurrence (%) and mean speed for each summer.

3.4 Wind Predominance and Speed Throughout the Summers of 2008-2015

Wind occurrence and speed patterns for each summer along the period 2008-2015 are shown in Figure 8. Winds from the whole N sector (N, NW, NE, NNW, NNE) dominated during all summers (Figure 8) and showed a decrease from summer 2008 (5.1 m s^{-1}) to summer 2015 (1.6 m s^{-1}) (Figure 8, see wind roses). Particularly, N winds were more frequent in most of the summers, with frequencies of occurrence between 13.3 and 21.3 %. Exception was observed in summer 2009 and 2013 when NNE and NW winds dominated (42.2 and 11.9 %, respectively) (Figure 8). Prevailing winds (N-NNW-NW) were significantly higher in summer 2008 than in 2015 (5.2 ± 0.2 and 2.6 ± 0.5 m s^{-1} respectively; Mann-Whitney U test, W=9292.50; $p<0.0001$) blowing at both summers for similar time duration (11h19m ± 05h52m in 2008 and 12h31m ± 6h13m in 2015, Mann-Whitney U test, W=6009; p=0.4796). This result is clearly evident in the vector plots, in which the length of the vectors decreased noticeably over the summers (Figure 8). The highest frequencies of occurrence of S winds were detected during the summers 2014 and 2015 (close to 10 %) (Figure 8 continuation). Comparing summers 2008 and 2015 in relation to whole S sector winds, it is evident that in 2008 there was a higher variation in the direction, whereas in 2015 S winds dominated most of the period (Figure 8, see vector plots). Winds from S sector were less frequent but more intense than N winds during both periods (means of 8.7 m s^{-1} in summer 2008 and 3.9 m s^{-1} in summer 2015).

3.4.1 Wind Associated to Coastal Upwelling: Analyses Between the Summers of 2008 and 2015

Offshore winds (WNW-ENE) were higher in summer 2008 than 2015 (mean speed 5.5 m s^{-1} in 2008 and 1.6 m s^{-1} in 2015). As it was already mentioned, summer 2008 and 2015 corresponded to periods of high occurrence and absence of medusae, respectively (Figure 2). The number of days of winds associated to coastal upwelling and consequently to medusae occurrence (winds blowing 10 hours straight from WNW to ENE at 3.3 m s^{-1} or more), were consistently higher in summer 2008 than in summer 2015 (Figure 9). In December 2007, 19 days showed that wind condition in contrast to 4 in December 2014 (Figure 9A). In January 2008, 15 days of medusae-associated winds occurred while only 4 days happened during January 2015 (Figure 9B). They accounted for up to 11 days in February 2008 while any day of medusae-associated winds was found in February 2015 (Figure 9C).

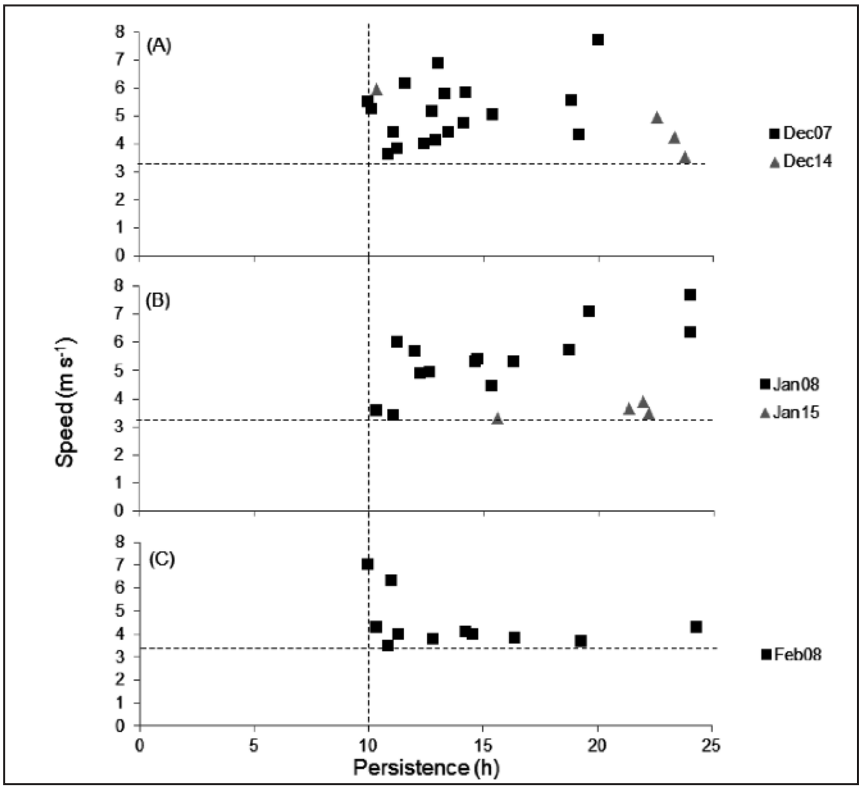


Figure 9 Number of days with winds associated to medusae occurrence during summer 2008 and 2015. (A) December, (B) January, (C) February. Dashed lines pointed the lowest persistence and speed values of medusae-associated winds (10 h or more WNW-ENE winds blowing at ≥ 3.3 m s^{-1}).

4 Discussion

4.1 Shifts in Wind and Temperature Patterns Along 2008-2015 in Monte Hermoso

A quantifiable change in wind speed was detected in Monte Hermoso throughout the period 2008-2015. Moderate and strong winds decreased importantly. In relation to wind predominance, N-NNW-NW winds were dominant all over the period, consistent with the typical pattern described for the region (Martos & Piccolo, 1988; Huamantinco Cisneros & Piccolo, 2010; Delgado *et al.*, 2012).

Different changes in atmospheric processes have been previously reported for the southwestern Atlantic Ocean (Gregg & Conkright, 2002; Severov *et al.*, 2004; Simionato *et al*., 2005; Dragani *et al.*, 2013; Pescio *et al*., 2015), and in particular for the Argentine platform (Martos & Piccolo, 1988; Lucas *et al.*, 2005; Auad & Martos, 2012; Delgado *et al.*, 2012). The passage of cyclones produced from baroclinic and lee topographic instability of the westerlies seemed to cause the high temporal variability of the winds over the southeastern South Atlantic (Gan & Rao, 1991). The wind variability in this region features a seasonal cycle that is strongly linked to the position and strength of the South Atlantic high-pressure system (Martos & Piccolo, 1988; Castro & Miranda, 1998; Auad & Martos, 2012). In summer, the atmospheric mean circulation changes as the South Atlantic high-pressure cell migrates southward (~32°S), generating E-NE winds become the prevailing winds between 18°S and 40°S (Pimenta *et al.*, 2008). Therefore, the changes in the wind pattern detected in Monte Hermoso could be associated to changes in the position and speed of this high-pressure system. Given that the dynamic of this coastal ecosystem is strongly modulated by tidal and wind forcing (Auad & Martos, 2012; Delgado *et al.*, 2014), significant changes in the wind pattern would have considerable effects on the ecosystem dynamic.

Shifts in the sea surface temperature were also suggested in Monte Hermoso, revealing that the sea surface become especially warmer in the last two years. The SST showed an increase over the study period of 0.4°C, in accordance with the warming trend of the sea and land surface detected globally (Casey & Cornillon, 2001; Stocker, 2013). Particularly, for the Argentine platform (34°-55°S), positive temperature anomalies and trends have been reported by several authors. For instance, Agosta and Campugnucci (2008) found a significant positive trend of SST along the period 1948-1977, and Martinez Avellaneda (2005) recorded positive anomalies (+0.4 °C between 1985-1999) and a positive tendency throughout the whole Argentine platform. Lucas *et al*. (2005) suggested difference of +3 °C in the SST during spring/summer (1993-1999) between north and south of 38°S and Auad & Martos (2012) revealed positive anomalies (lower than +2 °C) of the SST over the period 2000-2008 for an area comprised by 34°S-41°W/63°S-51°W. Although a previous study performed between 2002 and 2010 in the adjacent shelf of Monte Hermoso (39°S-61°W) showed the absence of significant interannual variability of the sea temperature (Delgado *et al.*, 2014), our results revealed positive annual anomalies (maximum of +0.6 °C) over the period 2008-2015 and a concentration of negative anomalies in the first part of the study period (from 2008 to 2012) suggesting, although minimal, a positive trend for the 8-yr period. Finally, it is important to highlight that there are conclusive evidences that the Argentine platform is affected by El Niño-Southern Oscillation (ENSO) (Severov *et al.*, 2004; Martínez Avellaneda, 2005; Delgado *et al.*, 2015), which would influence the SST adding an extra climatological forcing acting on the modulation of the temperature variability.

4.2 Variations in the Coastal Occurrence of *O. sambaquiensis* in Monte Hermoso: Explanations Associated to the Observed Environmental Change

The relationship between wind dynamic and the geomorphology of the coast can influence the distribution of medusa causing them to concentrate or swarm near to the shore (Kaneshiro & Kimmel, 2015). For instance, the occurrence of *Chrysaora quinquecirrha* (Scyphozoa) into the Neuse River Estuary has been reported as a function of wind-driven circulation (Kaneshiro & Kimmel, 2015). In Cable Beach (north-western Australia), on the other hand, stranding events of the scyphozoan *Crambione mastigophora* occurred when winds blow onshore (Keesing *et al.*, 2015).

Offshore winds can trigger coastal upwelling, producing that nutrients and plankton which originally were in the deeper water layer go upward

(Barua, 2005). This phenomenon explains why, during summers of high abundances of medusae, they reach the coastal waters of Monte Hermoso when local winds blow offshore for a long enough period (Varela, 1982; Mianzan & Zamponi, 1988). A number of 500 to 1000 stingings per day used to be reported in Monte Hermoso during those summers (Mosovich & Young, 2012). However, as far as we know, no one stinging accident has been reported in recent summers coinciding with the wind-pattern change. It is evident that wind is an important factor that influences medusae-human encounters in Monte Hermoso. Therefore, a change in wind pattern will have a relevant impact not only in the dynamic of the coast but also in the tourist influx to this beach.

On the other hand, as it is widely known, sea temperatures is one of the main environmental factors influencing the distribution and abundance of medusae communities (Arai, 1992; Purcell, 2005; Primo *et al.*, 2012; Schiariti *et al.*, 2014). Although different medusae species may respond differently to changing environmental conditions and same species may also differ by region (Lucas *et al.*, 2012), the general trend for temperate gelatinous species is that warm temperatures lead to greater and more rapid production (Purcell, 2005). Regardless of the fact that blooms may be defined phylogenetically by the asexual modes each species develops (Schiariti *et al.*, 2014), temperature (and salinity) both may affect positively or negatively the asexual reproduction rates of medusae directly through metabolism, and indirectly through prey capture (Purcell, 2005; Decker *et al.*, 2007). In the case of *Olindias* genera, Patry *et al*. (2014) found that temperature interacts differently with the polyp and the medusa. According to their results, *Olindias formosus* hydroids persisted only at 15°C, with regular asexual reproduction, and were lost at temperatures higher than 20°C. Medusae of this species were produced at temperatures higher than 15°C, growing larger and in better health condition at 20°C (Patry *et al.*, 2014). The results correlated with the seasonal influence of the Kuroshio Current off coastal Japan where the research was experimentally conducted, revealing a close relation with the factors that may affect the environment (Patry *et al.*, 2014). Based on all these findings, we could think that changes in the environment as a rise in temperature in winter may have a direct negative effect on the polyp asexual reproduction of *O. sambaquiensis*, which it could have negative consequences in the production rate of medusae during subsequent summers.

Given that in the last years, specimens of *O. sambaquiensis* were not found in plankton samples along the coastal area (Dutto *et al*., 2017; this study), an environmental regulation would be acting on the population dynamic of the species. If medusae were in the water column, the change in the wind pattern would probably prevent medusae reach the coast, but we do not have evidences that this change in wind magnitude is impacting on medusae reproduction or if it could impact it. The true is that the species has not been seen in the coastal waters of Monte Hermoso since summer 2013, and this may be probably in part due to an environmental regulation acting on the water column along with the lack of the physical phenomenon (*i.e.* coastal upwelling) that allow medusae reach the coast.

Our results evidence a significant decrease from 2008 to 2015 in the speed of offshore winds which significantly impacted in the number of days of meteorological conditions associated to coastal upwellings over the period. Persistent, low-speed offshore winds would not cause the phenomenon of upwelling. These results implied an important environmental change for this coastal region considering that days with intense and persistent N winds used to be the typical climatic condition for the area (Martos & Piccolo, 1988; Perillo & Cuadrado, 1990; Huamantinco Cisneros & Piccolo, 2011; Delgado *et al.*, 2012). Under the current meteorological conditions, not conducive to the occurrence of upwellings, medusae that inhabit the deeper layers would not reach the coast if they were actually there. Although studies under controlled environmental condition (*e.g.* temperature and salinity) are needed to explain the variation in the population dynamic of *O. sambaquiensis* in the coastal ecosystem of Monte Hermoso and surroundings, our results could be closely associated to the observed change in the occurrence pattern of this species.

5 Acknowledgments

The authors are grateful to CONICET and UNS for the financial support. Also, this work was carried out with the aid of a grant from the Inter-American Institute for Global Change Research

(IAI) CRN3038 which is supported by the US National Science Foundation (Grant GEO-1128040); we would like to thank to Alejandro Vitale, Luciano Salotto for technical assistance and Ana Laura Delgado for valuable comments on the first draft of the manuscript; thanks are also due to Paula Costilla and Alvaro Migotto for allowing us their photos.

6 References

Agosta, E.A. & Compagnucci, R.H. 2008. The 1976/77 Austral summer climate transition effects on the atmospheric circulation and climate in southern South America. *Journal of Climate*, 21 (17): 4365-4383.

Arai, M.N. 1992. Active and passive factors affecting aggregations of hydromedusae: a review. *Scientia Marina*, 56 (2): 99-108.

Auad, G. & Martos, P. 2012. Climate variability of the Northern Argentinean Shelf circulation: impact on *Engraulis Anchoita*. *International Journal of Ocean and Climate Systems*, 3 (1): 17-43.

Barua, D.K. 2005. Coastal upwelling and downwelling. *In*: SCHWARTZ, M.L. (Ed.), *Encyclopedia of Coastal Science*, The Netherlands: Springer, p. 306-308.

Caló, J.; Fernández, E.; Marcos, A. & Aldacour, H. 2005. Observaciones litorales ambientales de olas, corrientes y vientos de la playa de Monte Hermoso entre 1996 y 1999. *Geoacta*, 30: 27-38.

Carcedo, M.C.; Fiori S.M.; Piccolo M.C.; López Abbate, M.C. & Bremec, C.S. 2015. Variations in macrobenthic community structure in relation to changing environmental conditions in sandy beaches of Argentina. *Estuarine, Coastal, and Shelf Science*, 166: 56-64.

Casey, K.S. & Cornillon, P. 2001. Global and regional sea surface temperature trends. *Journal of Climate*, 14 (18): 3801-3818.

Castro, B.M. & Miranda, L.B. 1998. Physical oceanography of the western Atlantic continental shelf between 4° N and 34° S. *In:* ROBINSON, A. & BRINK, K. (Eds.), The Global Coastal Ocean, Multiscale interdisciplinary processes, USA: John Wiley and Sons, p. 209-251.

Chiaverano, L.; Mianzan, H. & Ramírez, F. 2004. Gonad development and somatic growth patterns of Olindias sambaquiensis (Limnomedusae, Olindiidae). *In:* FAUTIN, D.G.; WESTFALL, J.A.; CARTWRIGHT, P.; DALY, M. & WYTTENBACH, C.R. (Eds.), *Proceedings, Coelenterate Biology* 2003: *Trends in Research on Cnidaria and Ctenophora,* Hydrobiologia, p. 373-381.

Clarin,2013.http://www.clarin.com/sociedad/Monte-Hermoso-Pehuen-Co-aguavivas_0_868713178.html (last accessed 10 November 2015).

Decker, M.B.; Brown, C.W.; Hood, R.R.; Purcell, J.E.; Gross, T.F.; Matanosky, J.C.; Bannon, R.O. & Setzler-Hamilton, E.M. 2007. Development of habitat models for predicting the distribution of the scyphomedusa, *Chrysaora quinquecirrha*, in Chesapeake Bay. *Marine Ecology Progress Series*, 329: 99-113.

Delgado, A.L.; Vitale, A.J.; Perillo, G.M.E. & Piccolo, M.C. 2012. Preliminary analysis of waves in the coastal zone of Monte Hermoso and Pehuén Co, Argentina. *Journal of Coastal Research*, 28 (4): 843-852.

Delgado, A.L.; Jamet, C.; Loisel, H.; Vantrepotte, V.; Perillo, G.M.E. & Piccolo, M.C. 2014. Evaluation of the MODIS-aqua sea-surface temperature product in the inner and mid-shelves of southwest Buenos Aires province, Argentina. *International Journal of Remote Sensing*, 35 (1): 306-320.

Delgado, A.L.; Loisel, H.; Jamet, C.; Vantrepotte, V.; Perillo, G.M.E. & Piccolo, M.C. 2015. Seasonal and inter-annual analysis of chlorophyll-a and inherent optical properties from satellite observations in the inner and mid-shelves of the south of Buenos Aires province (Argentina). *Remote Sensing*, 7: 11821-11847.

Delgado, A.L.; Menéndez, M.C.; Piccolo, M.C. & Perillo, G.M.E. 2016. Hydrography of the inner continental shelf of the southwest Buenos Aires Province, Argentina: influence of an estuarine plume on coastal waters. *Journal of Coastal Research,* 33 (4): 907 – 916.

Dragani, W.C.; Martin, P.B.; Alonso, G.; Codignotto, J.O.; Prario, B.E. & Bacino, G. 2013. Wind wave climate change: Impacts on the littoral processes at the northern Buenos Aires province coast, Argentina. *Climate Change*, 121: 649-660.

Dutto, M.S.; Genzano, N.G.; Schiariti A.; Lecanda J.; Hoffmeyer M.S. & Pratolongo, P. 2017. Medusae and ctenophores from the Bahía Blanca Estuary and neighboring inner shelf (Southwest Atlantic Ocean, Argentina). *Marine Biodiversity Records,* 10-14.

Estación de Monitoreo Ambiental Costero (EMAC), 2016.

Gan, M.A. & Rao, V.B. 1991. Surface cyclogenesis over South America. *Monthly Weather Review*, 119: 1293-1302.

Garreaud, R.D. & Battisti D.S. 1999. Interannual (ENSO) and interdecadal (ENSO-like) variability in the southern hemisphere tropospheric circulation. *Journal of Climate*, 12: 2113-2123.

Gómez Erache, M.; Norbis, W. & Bastreri, D. 2000. Wind effect as forcing factor controlling distribution and diversity of copepods in a shallow temperate estuary (Solís Grande, Uruguay). *Scientia Marina*, 64 (1): 87-95.

Graham, W.M.; Pagès, F. & Hamner, W.M. 2001. A physical context for gelatinous zooplankton aggregations: a review. *Hydrobiologia*, 451: 199-212.

Gregg, W.W. & Conkright, M.E. 2002. Decadal changes in global ocean chlorophyll. *Geophysical Research Letters*, 29 (15): 201–204, doi:10.1029/2002GL014689.

Hoffmeyer, M.S.; Menéndez, M.C.; Biancalana, F.; Nizovoy, A.M. & Torres, E.R. 2009. Ichthyoplankton spatial pattern in the inner shelf off Bahía Blanca Estuary, SW Atlantic Ocean. *Estuarine, Coastal and Shelf Science*, 84: 383-392.

Huamantinco Cisneros, M.A. & Piccolo, M.C. 2010. Índices de confort aplicados al balneario de Monte Hermoso, Argentina. *Revista Investigaciones Geográficas*, 52: 201-214.

Huamantinco Cisneros, M.A. & Piccolo, M.C. 2011. Caracterización de la brisa de mar en el Balneario de Monte Hermoso, Argentina. *Estudios Geográficos*, 271: 461-475.

Huamantinco Cisneros, M.A. 2012. *Efecto de la variabilidad climática del balneario Monte Hermoso sobre su geomorfología costera y el confort climático*. PhD, Universidad Nacional del Sur, Bahía Blanca, Argentina, p.262._

Ingle, Jr., J.C. 1999. Atmosphere-ocean coupling and surface circulation of the ocean. *In:* ERNST, W.G. (Ed.), *Earth Systems: Processes and Issues*, Cambridge Univ. Press, p. 152-169.

Kalnay, E.; Kanamitsu, M.; Kistler, R.; Collins, W.; Deaven, D.; Gandin, L.; Iredell, M.; Saha, S.; White, G.; Woollen, J.; Zhu, Y.; Leetmaa, A.; Reynolds, B.; Chelliah, M.; Ebisuzaki, W.; Higgins, W.; Janowiak, J.; Mo, K. C.; Ropelewski, C.; Wang, J.; Jenne, R. & Joseph, D. 1996. The NCEP/NCAR Reanalysis 40-year Project. *Bulletin of the American Meteorological Society*, 77(3): 437-471.

Kaneshiro-Pineiro, M.Y. & Kimmel, D. 2015. Local wind dynamics influence the distribution and abundance of *Chrysaora quinquecirrha* in North Carolina, USA. *Estuaries and Coasts*, 38 (6): 1965-1975.

Keesing, J.K.; Gershwin, L.; Trew, T.; Strzelecki, J.; Bearham, D.; Liu, D.; Wang, Y.; Zeidler, W.; Onton, K. & Slawinski, D. 2015. Role of winds and tides in timing of beach strandings, occurrence, and significance of swarms of the jellyfish *Crambione mastigophora* Mass 1903 (Scyphozoa: Rhizostomeae: Catostylidae) in north-western Australia. *Hydrobiologia*, 768 (1): 19-36.

La Nación, 2013. http://www.lanacion.com.ar/1541784-adviertensobre-los-riesgos-de-las-aguavivas-en-la-costa (last accessed 20 December 2015).

La Nueva, 2015. http://www.lanueva.com/la-region/793597/monte-hermoso--otro-verano-sin-aguas-vivas-es-lo-mejor-que-nos-puede-pasar.html (last accessed 20 March 2015).

Lucas, A.J.; Guerrero, R.A.; Mianzan, H.W.; Acha, E.M. & Lasta, C.A. 2005. Coastal oceanographic regimes of the Northern Argentine Continental Shelf (34-43ºS). *Estuarine, Coastal and Shelf Science*, 65: 405-420.

Lucas, C.H.; Graham, W.M.; Pagés, F.; Hamner, W.M. & Widmer, C. 2012. Jellyfish life histories: role of polyps in forming and maintaining Scyphomedusa populations. *Advances in Marine Biology*, 63: 133-196.

Martínez Avellaneda, N. 2005. *Ciclo anual y variabilidad de baja frecuencia de la temperatura superficial del mar en el Océano Atlántico Sudoccidental*. PhD, Universidad de Buenos Aires, Buenos Aires, Argentina, p. 143.

Martos, P. & Piccolo, M.C. 1988. Hydrography of the Argentine continental shelf between 38º and 42ºS. *Continental Shelf Research*, 8 (9): 1043-1056.

Mc Connaughey, B.H. 1982. Coastal waters habitat. *In:* SCHWARTZ, M.L. (Ed.), *The Encyclopedia of beaches and coastal environments*, Stroudsburg, Pennsylvania: Hutchinson Ross Publishing Company, p. 322-324.

Menéndez, M.C.; Piccolo, M.C. & Hoffmeyer, M.S. 2012. Short-term variability on mesozooplankton community in a shallow mixed estuary (Bahía Blanca, Argentina): Influence of tidal cycles and local winds. *Estuarine, Coastal and Shelf Science*, 112: 11-22.

Menéndez, M.C.; Fernández Severini, M.D.; Buzzi, N.S.; Piccolo, M.C. & Perillo G.M.E. 2016. Assessment of surf zone environmental variables in a southwestern Atlantic sandy beach (Monte Hermoso, Argentina). *Environmental Monitoring and Assessment*, 188: 495-507.

Mianzan, H.W. & Zamponi, M.O. 1988. Estudio bioecológico de *Olindias sambaquiensis* Müller, 1861 (Limnomedusae, Olindiidae) en el área de Monte Hermoso, II. Factores meteorológicos que influyen en su aparición. *Iheringia*, 2: 63-68.

Mianzan, H.W.; Fenner, P.J.; Cornelius, P.F.S. & Ramírez, F.C. 2001. Vinegar as a disarming agent to prevent further discharge of the nematocysts of the stinging hydromedusa *Olindias sambaquiensis*.*Cutis*, 68 (1): 45-48.

Mosovich, J.H. & Young, P. 2012. Picadura de medusa *Olindias sambaquiensis*. Análisis de 49 casos. *Medicina*, 72: 380-388. Página95, 2013. http://pagina95.com/2013/02/04/el-verano-en-monte-hermoso-se-vive-sin-aguas-vivas/(last accessed 15 March 2015).

Patry, W.; Knowles, T.; Christianson, L. & Howard, M. 2014. The hydroid and early medusa stage of *Olindias formosus* (Cnidaria, Hydrozoa, Limnomedusae). *Journal of the Marine Biological Association of the United Kingdom*, 94 (7): 1409-1415.

Perfil,2012.http://www.perfil.com/ediciones/2012/2/edicion_652/contenidos/noticia_0058.html%3b (last accessed 20 June 2015).

Perillo, G.M.E. & Cuadrado, D.G. 1990. Near surface suspended sediments at Monte Hermoso beach, Argentina: I. Descriptive characteristics. *Journal of Coastal Research*, 6 (4): 981-990.

Pescio, A.E.; Martin, P.B. & Dragani, W.C. 2015. Wind speed trends over the southwestern Atlantic Ocean, between 33º and 50ºS. *International Journal of Climatology*, 36 (1): 501-507.

Piccolo, M.C. 1998. Oceanography of the western South Atlantic continental shelf from 33° to 55°S. *In:* ROBINSON, A.R. & KENNETH, H.B. (Eds.), *The Sea*, vol. 11. John Wiley & Sons, Inc., p. 253-271.

Primo, A.L.; Marques, S.C.; Falcão, J.; Crespo, D.; Pardal, M.A. & Azeiteiro, U.M., 2012. Environmental forcing on jellyfish communities in a small temperate estuary. *Marine Environmental Research*, 79: 152-159.

Purcell, J.E. 2005. Climate effects on formation of jellyfish and ctenophore blooms: a review. *Journal of the Marine Biological Association of the United Kingdom*, 85: 461-476.

Purcell, J.E. & Decker, M.B. 2005. Effects of climate on relative predation by scyphomedusae and ctenophores on copepods in Chesapeake Bay during 1987-2000. *Limnology and Oceanography*, 50 (1): 376-387.

Rojas, M.L.; Recalde, M.Y.; London, S.; Perillo, G.M.E.; Zilio, M.I. & Piccolo, M.C. 2014. Behind the increasing erosion problem: The role of local institutions and social capital on coastal management in Argentina. *Ocean and Coastal Management*, 93: 76-87.

Schiariti, A.; Morandini, A.C.; Jarms, G., Paes, R.G.; Franke, S. & Mianzan, H. 2014. Asexual reproduction strategies and blooming potential in Scyphozoa. *Marine Ecology Progress Series*, 510: 241-253.

Servicio de Hidrografía Naval Argentina, 2016. Tabla de mareas. http://www.hidro.gov.ar. (last accessed 15 March 2015)

Severov, D.N.; Mordecki, E. & Pshennikov, V.A. 2004. SST anomaly variability in Southwestern Atlantic and El Niño/Southern oscillation. *Advance in Space Research*, 33: 343-347.

Simionato, C.G.; Vera, C.S. & Siegismund, F. 2005. Surface wind variability on seasonal and interannual scales over Río de la Plata area. *Journal of Coastal Research*, 21 (4): 770-783.

Simmonds, I. & Keay, K. 2000. Mean Southern Hemisphere Extratropical Cyclone Behavior in the 40-Year NCEP–NCAR Reanalysis. *Journal of Climate*, 13: 873-885.

Sousa, M.C.; Alvarez, I.; Vaz, N.; Gómez-Gesteira, M. & Dias, J.M. 2012. Análisis de la precisión de los datos de viento obtenidos del satélite QuikSCAT y el modelo WRF en la costa gallega. *Revista Avances en Ciencias de la Tierra*, 3: 39-53.

Stocker, T.F.; Qin, D.; Plattner, G.K.; Alexander, L.V.; Allen, S.K.; Bindoff, N.L.; Bréon, F.M.; Church, J.A.; Cubasch, U.; Emori, S.; Forster, P.; Friedlingstein, P.; Gillett, N.; Gregory, J.M.; Hartmann, D.L.; Jansen, E.; Kirtman, B.; Knutti, R.; Krishna Kumar, K.; Lemke, P.; Marotzke, J.; Masson-Delmotte, V.; Meehl, G.A.; Mokhov, I.I.; Piao, S.; Ramaswamy, V.; Randall, D.; Rhein, M.; Rojas, M.; Sabine, C.; Shindell, D.; Talley, L.D.; Vaughan, D.G. & Xie, S.P., 2013. Technical Summary. *In:* Stocker, T.F.; Qin, D.; Plattner, G.K.; Tignor M.; Allen, S.K.; Boschung J.; Nauels, A.; Xia, Y.; Bex, V., and Midgley, P.M. (Eds.), *Climate Change 2013: The Physical science basis*, Contribution of working group I to the Fifth assessment report of the intergovernmental panel on climate change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p.33-115.

Vaquero, M. del C.; Rodríguez, C. & Trellini, M. 2007. El turismo residenciado en Monte Hermoso. *In: IV JORNADAS INTERDISCIPLINARIAS DEL SUDOESTE BONAERENSE* (Bahía Blanca, Argentina), 201-206.

Varela, P.A. 1982. Un estudio de la brisa de mar en Monte Hermoso e Ingeniero White. *Revista Geofísica*, 17: 73-85.

Villate, F. 1997. Tidal influence on zonation and occurrence of resident and temporary zooplankton in a shallow system (Estuary of Mundaka, Bay of Biscay). *Scientia Marina*, 61 (2): 173-188.

Villate, F. 1994. Temporal variability of the spatial distribution of the zooplankton community in a coastal embayment of the Basque country in relation to physical phenomena. *Hydrobiologia*, 288: 79-95.