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Joint ICES/AOSB Theme Session D

The role of the Arctic and Sub-Arctic in a climate change perspective

Conveners: Harald Loeng (Norway) and Bogi Hansen (Faroe Islands)

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Imprint of the North Atlantic climate on the long term hydroclimate changes in the Gulf of Mexico

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Abstract

Climate teleconnections link large scale regions through the transient behavior of atmospheric waves. In the Atlantic Ocean, one of the most prominent teleconnections is the North Atlantic Oscillation (NAO), which together with the Arctic Oscillation (AO) constitutes regional manifestations of the Northern Annular Mode (NAM), closely linked to the leading pattern of sea surface temperature (SST). Here we have examined the potential influence such meteorological phenomenon has on patterns of low frequency variability of hydroclimate conditions fisheries in the Gulf of Mexico (GoM). Statistical analyses were performed using large- (NAO/AO) and regional scale (GoM climate) data and time series of GoM fish captures over the period 1980-2010. Results show significant correlative associations between the GoM hydroclimate variability and the North Atlantic climate over the period 1950-2010. The oscillation frequency of some hydroclimatic variables, the NAO/AO and some catch time series showed common peaks. The relationship, however, shows a transient behavior leaded by the varying dominant period of the climatic teleconnection. The close link between large-scale atmospheric forcing and regional environmental conditions suggest cascade down effects on plankton communities and/or changes in reproductive habitat for fish. The long periods of alternated low and high SST, likely coupled to the Atlantic Multidecadal Oscillation, can alter both food sources for fish larvae (i.e. changes in zooplankton structure) and the thermal window for mass reproduction of fish.

Keywords: Time series, climate variability, North Atlantic Oscillation (NAO), Arctic oscillation (AO), Gulf of México (GoM).

INTRODUCTION

The term “teleconnection” is defined as “the linkage between weather changes occurring in widely separated regions of the globe” (American Meteorological Society, 2000; Nigam, 2003; Ruiz-Barradas & Tejeda-Martínez, 2009). The Arctic Oscillation (AO) and the North Atlantic Oscillation (NAO) represents the most important teleconnection patterns in the North Atlantic Ocean (Chao, *et al*., 2011), the former, also known as Northern Hemisphere Annular Mode (NAM), is defined by the difference in the normalized monthly sea level pressure (SLP) between 35^{o}N and 65^{o}N (Thompson & Wallace, 1998; Li & Wang, 2003), while the NAO is an alternation of atmospheric pressure between the subtropical zones (Azores, high pressure) and the area over Iceland (low pressure) (Walker & Bliss, 1932; Barnsto & Livezei, 1987, Ottersen *et al.,* 2001, Meiners, 2007). Both the NAO and the AO are closely related because they affect the same atmospheric variable (the Sea Level Pressure) in different regions of the globe (Thompson & Wallace, 1998).

In this study we used these two important meteorological phenomena to examine their potential influence in the Gulf of México (GoM) and the indices of capture volume of commercially important coastal species in the GoM. The use of climate proxy decreases the complex variability in space and time of these phenomena and helps to the understanding of the nature of climate system (Stenseth *et al.*, 2003). The study comprised the entire GoM basin for the hidroclimatic variables (30^{o}N, 17.5^{o}S; –97.5^{o}W, -80^{o}E) (Fig. 1).

For the indices of capture volume, we used the Yearbook of fishery statistics of the Mexican states of Tamaulipas, Veracruz, Tabasco, Campeche and Yucatán (Fig. 2). The GoM has a maximum depth of 4000 m in the central region and communicates with the Atlantic Ocean by the Yucatán Channel, the Caribbean Sea and the Straits of Florida (Martinez & Parés, 1998). The wind flow and the mass transport through the Yucatán Channel and the Straits of Florida are the principal responsible for the circulation of ocean currents in the Gulf of Mexico. (Monreal Gómez & Salas Gómez de León, 2004).

The circulation in the GoM has two semi-permanent features: (1) The loop current (in the East) that consist in the warm water inflow from the Caribbean Sea by the Yucatán Current and join the Florida´s current through (2) an anticyclonic circulation cell (on the western border) that emerge from the loop current (Martinez & Parés, 1998, De Lanza-Espino & Gomez-Rojas, 2004). The GoM is governed by two major weather events (1) tropical storms and hurricanes, which are originated in subtropical latitudes and eventually move to the coasts; and (2) the "Nortes" which occur in the months from April to October when they hit cold air masses coming from dry land with tropical air masses of GoM (Monrreal-Gómez *et al*., 2004).

Due to the geographic location of the GoM and its close connection with subtropical Atlantic meteorological phenomena, we suspect that the hydroclimatic factors in the GoM can be, in part, related to the decadal variability of the North Atlantic Climate.

DATA AND METHODS

Climate data: We used annual standardized time series of hydroclimatic variables of the GoM taken from NOAA NCEP/NCAR data (1950-2010) (Kalnay *et al*. 1996), to have the overview of the weather in the GoM (Storch & Zwiers, 2003; Stenseth *et al*., 2003). The dataset includs the Geopotencial height 500mb (Gh), zonal wind (Zw), meridonal wind (Mw), air temperature (At), relative humidity (Rh), specific humidity (Sh), sea surface temperature (SST), sea level pressure (SLP), precipitation rate (Pr), precipitable water (Pw) and outgoing longwave radiation (OLR). More over, we used The NAO/AO index taken from Li & Wang, 2012 (NAO/LW and AOI/LW)

Fishery data: we gathered fishery statistics data from Yearbooks of Fishery Statistics from 1980 to 2010. This time series of fisheries were chosen following these criteria:

- That the series correspond to a single taxonomic species.
- That the extension of the series has at least 10 years.
- That the species chose belong to a different trophic level.

Data analysis: the GoM climate variability was assessed by means of Principal Component Analysis (PCA) on the matrix of regional hydro-meteorological factors (Jollife, 2002; Storch & Zwiers, 2003). The principal component 1 (PC1), which accounted for 38% of the total variance, was used as a proxy for the GoM climate variability.

We explored the potential relationship between the NAO/AO and GoM by means of Pearson correlations. Afterward we examined the relationship between local hydroclimate conditions in the GoM and fish catches.

An analysis of energy spectrum between the time series of hidroclimatic variables in the GoM and the NAO/AO index was made to found similarities in the oscillation frequencies. Additionally we correlated the time series of fisheries and the NAO/AO index and repeat an analysis of energy spectrum of the same datasets.

Statistical analysis was performed using MATLAB 7.8.0.347 (MathWorks Inc., 2009), STATISTICA 8.0 (StatSoft Inc., 2007) and WinIDAMS 1.3 (UNESCO, 2008).

RESULTS

The highest and significant correlation between the time series of the Hydroclimatic variables of the GoM and the time series of fisheries were obtained by the NAO/LW with Gh (r^2=0.20, p=0.0002) and At (r^2=0.22, p=0.0001); and AOI/LW with Gh (r^2=0.47, p=0), At (r^2=0.28, p=0.0001) and OLR (r^2=0.20, p=0.0003).

The PCA shows that the first principal component represents the 38% of the total variance of the hidroclimate in the GoM and the cumulative sum of the first four principal components represent the 83.3% of the total variance (Table 1). When we correlated the principal components with the NAO/AO index, found that all the significant correlations are direct (Table 2).

The analysis of the energy spectrum show that the hydroclimate of the GoM and the North Atlantic climate have constants oscillations in phase every 2, 3, 5 and in some cases 8 years (Table 3).

We selected the time series of two species that are commercially important in the coasts of the GoM 1) king mackerel (*Scomberomorus cavalla*) from 1995 to 2010 and 2) little tunny (*Euthynnus alletteratus*) from 1989 to 2010. Both time series from the states of Tamaulipas, Veracruz, Tabasco, Campeche and Yucatán.

The time series of the captures were correlated with the NAO/AO index and shows that *S. cavalla* from Campeche presents a significant and inverse correlation with the AOI/LW (r^2=0.36, p=0.0130) and NAO/LW (r^2=0.48, p=0.0028). The times series of this specie in the others states did not shows significant correlations.

In the case of *E. alleteratus* in Campeche we found a significant and inverse correlation between the captures in the state of Campeche and the AOI/LW (r^2=0.20, p=0.0363) and NAO/LW (r^2=0.34, p=0.0039). With this specie we did not found significant correlations in the captures of other states. The energy spectrum analysis showed oscillations in phase between the time series of these species and the NAO/AO index every 2, 3 and 4 years (Table 4).

CONCLUSION

There are preliminary evidences consistent with the hypothesis on the imprint of the North Atlantic climate in the GoM. Our results emphasize that the interaction NAO/AO with the regional hydroclimate variability occurs on different dominant periods and mainly through the geopotential height, outgoing longwave radiation and air temperature as mediator factor between the North Atlantic climate and the GoM. As shown by the PCA these atmospheric factors further drive the decadal patterns of the GoM climate, as shown by the PCA.

Modifications in the above regional atmospheric parameters interact directly with the sea surface temperature in the GoM, and might permeate plankton communities. In particular, growing evidence shows that temperature-related plankton changes involve modifications in structure (i.e. diversity, size), and quality (i.e. stoichiometry), which can alter not only food sources for fish larvae, but also the thermal window for mass reproduction of fish. Such interactions suggest cascade down effects from the large scale climate variability (NAO/OA) to the regional hydroclimatic variables of the GoM.

The analysis of energy spectrum shows that the climate – fish interaction is discontinuous over the time, with coherent variations at short periods (i.e. 2 years dominant periods). By showing the sensitivity of commercially important fish species to climate drivers in the Atlantic Ocean our results can have further utility as baseline for further studies in the southwest of the GoM and the development of fisheries management.

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Table 1. Eigenvalues of the PCA, the percentage of the total variance and the cumulative sum.

	Eigen values	% of the total variance	Cumsum of the % of the total variance
comp1	4.19	38.09	38.09
comp2	2.61	23.77	61.86
comp3	1.34	12.18	74.04
comp4	1.03	9.32	83.36

Table 2. Correlation coefficients between the principal components and the NAO/AO index.

	NAO/ LW	AOI/ LW
Comp 1	0.23	0.23
Comp 2	**0.37**	0.09
Comp 3	**0.42**	**0.44**
Comp 4	-0.05	-0.16

The marked correlations are significant at $p<0.05$.

Table 3. Periods of oscillations(in years) in phase between the hydroclimate of the GoM and the North Atlantic Climate.

	NAO/LW				AOI/LW			
Gh	2.06	5.45	8.57	15.00	2.06	5.45	8.57	15.00
Zw	2.06	3.15	8.57		2.06	3.00	8.57	
Mw	2.00	8.57			2.00	3.75	8.57	
At	2.06	5.45	8.57		2.06	5.45	8.57	
SST	2.50	5.45	8.57		2.00	5.45	8.57	
Rh	2.06	3.15	5.45	8.57	2.06	3.75	5.45	8.57
Sh	2.00	3.15	5.45		2.00	3.00	5.45	
SLP	2.22	3.14	5.45	8.57	2.00	3.00	5.45	8.57
Pr	2.06	3.15			2.06			
Pr	2.22	3.15	5.45	15.00	2.00	3.00	5.45	
OLR	2.06	3.15	8.57		2.06	3.00	8.57	

Table 4. Periods of oscillations in phase between the Catch-based time series and the North Atlantic Climate.

	NAO/LW	AOI/LW
S. cavalla **Campeche**	2.30	2.30
S. cavalla **Yucatan**	2.30	2.30
E. alletteratus **Campeche**	2.00 2.50 3.15	2.00
E. alletteratus **Tabasco**	2.50 4.30	2.30 4.30

The marked years (in red) are represented in the Figures 3 and 4.

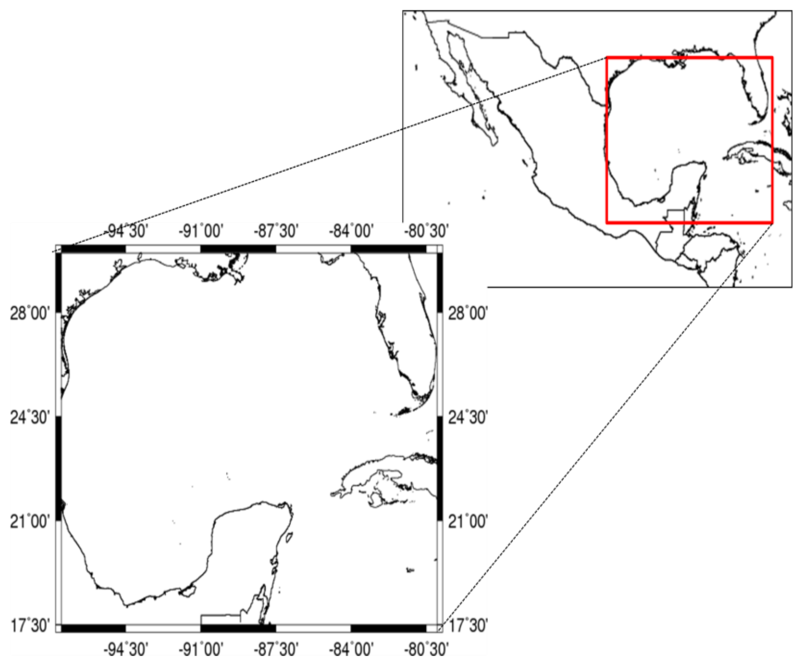

Fig. 1. Geographical localization of the GoM and the area where hydroclimatic variables were taken

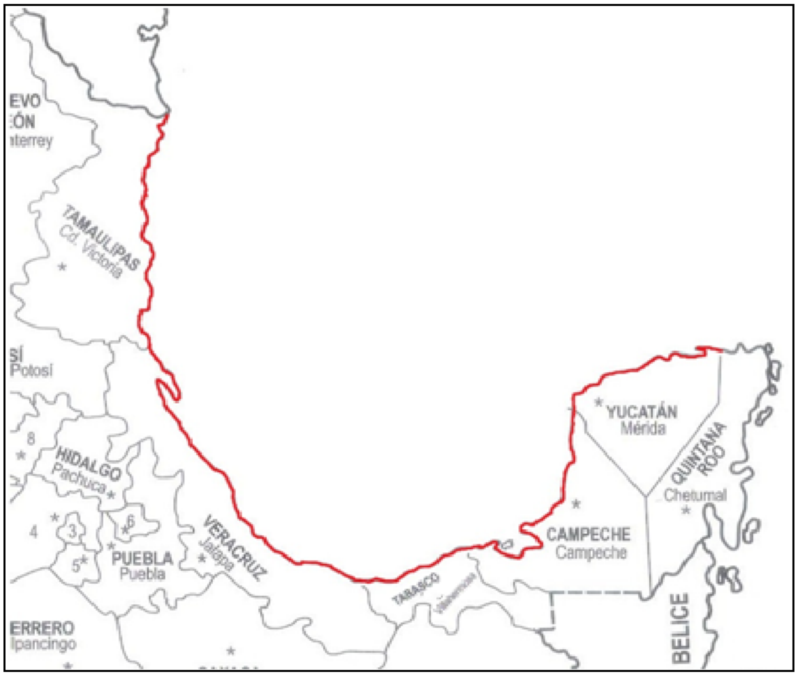

Fig. 2. Red line shows the states where we took the time series of fisheries in the GoM

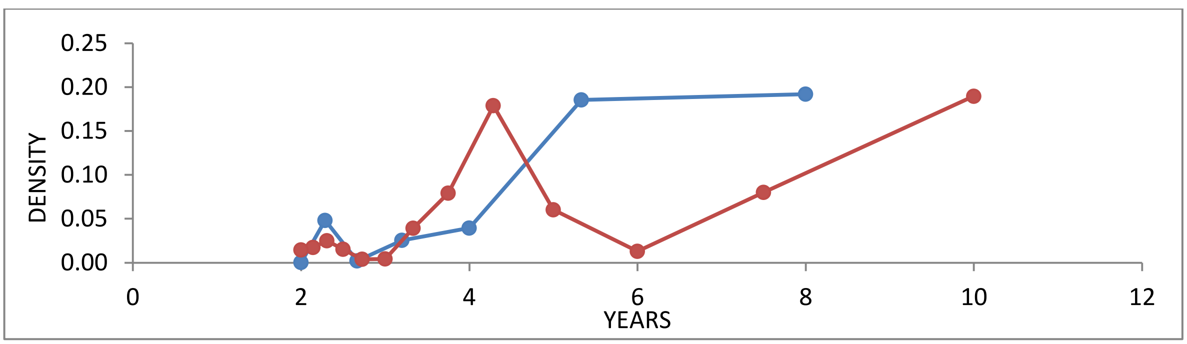

Fig. 3 Density of the oscillation frequencies between the AOI/LW (red line) and the *S. cavalla* from Campeche (blue line).

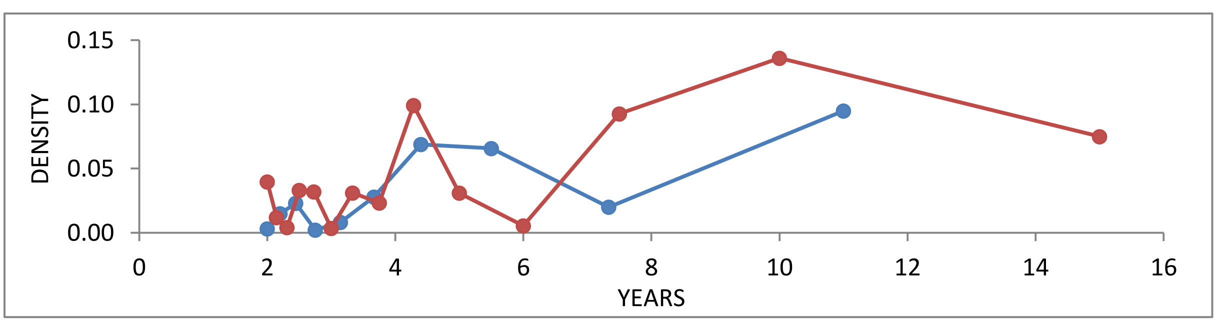

Fig. 4. Density of the oscillation frequencies between the NAO/LW (red line) and the *E. alletteratus* from Tabasco (Blue line).