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Could Thermal Oceanic Hotspot Increase Climate Changes Activities in North Tropical Atlantic: Example of the 2005 Caribbean Coral Bleaching Hotspot & Hurricane Katrina Interaction

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Abstract**—**This paper reviews recent studies and particularly the effects of Climate Change in the North Tropical Atlantic by studying atmospheric conditions that prevailed in 2005 ; Coral Bleaching HotSpot and Hurricane Katrina. In the aim to better understand and estimate the impact of the physical phenomenon, *i.e.* Thermal Oceanic HotSpot (TOHS), isotopic studies of $\delta^{18}O$ and $\delta^{13}C$ on marine animals from Guadeloupe (French Caribbean Island) were carried out. Recorded measures show Sea Surface Temperature (SST) up to 35°C in August which is much higher than data recorded by NOAA satellites 32°C. After having reviewed the process that led to the creation of Hurricane Katrina which hit New Orleans in August 29, 2005, it will be shown that the climatic conditions in the Caribbean from August to October 2005 have influenced Katrina evolution. This TOHS is a combined effect of various phenomenon which represent an additional factor to estimate future climate changes.

Keywords**—**Climate Change, Thermal Ocean HotSpot, Isotope, Hurricane, Connection, Uncertainty, Sea, Science.

I. Introduction

The climate is like a matrix where many complex forcing interact, causing disturbances at different levels; temporal, environmental, oceanographic, geological, atmospheric but also societal and urban. The factors that determine these disturbances involve subtleties, some of which still remain poorly understood and difficult to predict [1]. Three main loops of complex climate feedback related to an increase in CO_2 were diagnosed in climate prediction models: clouds, surface albedo and water vapor [2]-[3]. If one adds to these forces the Coral Bleaching HotSpot (CBH) and stresses of anthropogenic origin, one obtains a cocktail of varied and unpredictable risks, altering a little more the balance in climate and exerting extreme pressure on marine ecosystems and the wall oceans. Yet concerning the formation of Hurricane Katrina in august 2005, many aspects remain poorly understood. Indeed, no one has yet compiled all of the information [4] in order to identify opportunities and this is in part what will be done in this paper. Most hurricanes making landfall in the southern United States of America come from the Caribbean or off. Climate change models use various climate indices to characterize the cyclonic activity such as hurricane frequency, duration, depending on wind speed, evaporation level and the atmospheric pressure [5], category [6] and the energy accumulated by the cyclone [7], but not yet Thermal Oceanic HotSpot. Relations of cause and effect between the SST phenomena cause by TOHS which occur in tropical and subtropical north Atlantic areas, especially in the Caribbean in the end of the year 2005 and hurricanes are attracting more and more attention. Recent studies have shown that SST and the recurrence of more powerful hurricanes could be linked to climate change associate sustained, anomalously high summertime water temperature [8]-[9]-[10], anthropogenic stress. The Thermal anomaly is probably due principally to the effects of the El Nino Southern Oscillation (ENSO) [11] and recently, [11] was shown that the sea level on the American North Atlantic coast is rising faster than expected and this is due to climate change and TOHS.

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II. Climatic Context in August 2005

Most paper consider that Hurricane Katrina, which struck New Orleans on August 29, 2005 was formed in August 23, 2005 off from Cuba, and hit New Orleans with a category 5 on the scale of Saffir-Simpson, it's not completely true. Many factors influenced its evolution; at first one important atmospheric anomaly stabilized above the North Atlantic Tropical region during many months (fig. 1), characterized by CBH due to TOHS which caused SST rise on one important surface of the Caribbean Seas' and the North Tropical Atlantic. Please submit your manuscript electronically for review as e-mail attachments. When you submit your initial full paper version, prepare it in two-column format, including figures and tables. However, this anomaly concerned the wall World, of whom north regions like Canada, Greenland and in Russia which is in part sensible to hurricanes [12]. Secondly in contrary to what was widely diffused, the tropical depression which created Hurricane Katrina did not forms on August 23rd, 2005 in large of Cuba, but starting from one weather disturbance on August 13th off Barbados at 12:00 (fig. 2), in the Caribbean [13]. Despite the high performance of satellites, the margins of error still remain relatively important in some conditions [14]-[15] in some areas on the world, particularly in the tropics [16] where they can go from 6% to 30% depending on the technology [17].

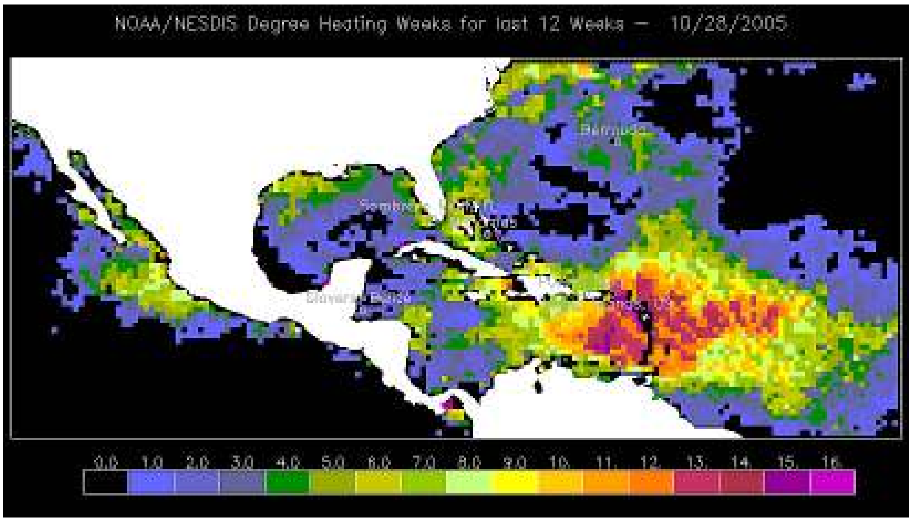

Fig. 1 HotSpot recorded in 2005. The figure represente the Degree Heating Weeks (DHW) recorded in the North Tropical Atlantic East area and the Caribbean's from August to October 10, 2005 Thermal HotSpot recorded in 2005. The figure 1 represent the Degree Heating Weeks (DHW) recorded in the North Tropical Atlantic East area and the Caribbean's from August to October 10, 2005

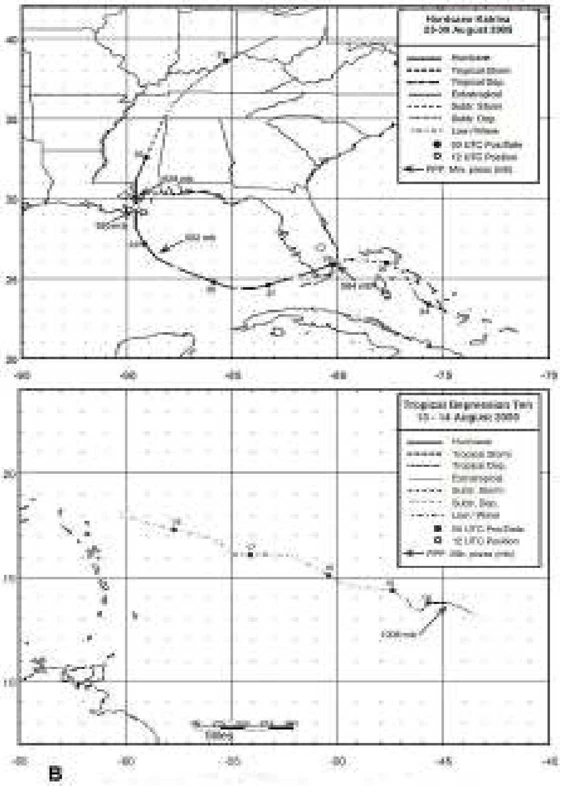

Fig. 2 Characteristic of Hurricane Katrina from 13 August, 2005 to 30 August 2005. Figure B represent the better way of the Weather Disturbance « Depression Ten », between 13th and 14th August 2005 at the origin of Hurricane Katrina. Source first figure, Knabb, Rhome, Brown, 2005. Source fig.b; Beven, 2006

Specifically figure 2b shows the « Tropical Disturbance Ten » which is the starting point of Hurricane Katrina. The blackpoints indicate the dates and the graypoints inform about the position at one specific time. The position of disturbance at August 18, 2005 is off to Guadeloupe archipelago, consequently on the zone covered by the TOHS. Figure -2b- shows the « Tropical Disturbance Ten » which is the starting point of Hurricane Katrina. The blackpoints indicate the dates and the graypoints inform about the position at one specific time. The position of disturbance at august 18, 2005 is off to Guadeloupe archipelago, consequently on the zone covered by the TOHS.

Then, the weather disturbance moved slowly from 13th August before degenerating on August 18th in the North-East of the Lesser Antilles. In front of the seas of Guadeloupe Archipelago. Thereafter a complex system was formed moving in the west before dissipating on August 21st off Cuba. In the aim to understand what happened from 13th still 21 august in the Caribbean's region, isotopic studies was made on marine animals. Isotopic studies were carried out on indicators known for their precision, corals, to obtain precise SST measures in the Lesser Antilles and compare them with the temperatures measured by satellite of USA. Corals are animals which are very sensitive to changes in temperature [18]-[19] and record a lot of information during the calcification process of their skeleton as climate change. Coral reefs are also the most vulnerable ecosystems to climate change [20]. By comparing the information compiled using the two main technologies (isotopic studies and meteorology), it could to be possible to make some corrections on the measurement made using radar and satellite systems, the latter still remaining relatively sensitive to clouds, rain and wind [21]-[22].

A. The Thermal Ocean HotSpot

At first, it's necessary to clarify the concept of HotSpot which is used in this paper. Hotspot have been tainted by confusion between many concepts. The first concerned "biodiversity hotspots" which represent one high concentration of biodiversity and/or a high conservation value [23]. Coral Bleaching HotSpot (CBH) is one index of thermal stress recorded by corals due to a rise of 1°C SST over the normal means [24] but also some degrees lower about the normal mean SST. When the effects of coral bleaching hotspot in the Gulf of Mexico were first identified with accuracy in the 1950s [25], it was noted that a wide variety of marine animals, including fish, had been disturbed and disoriented by their effect and that many corals had perished. Two previous coral bleaching HotSpot were recorded as being exceptional in 1998 and 2002, killing more than 99% of corals of the genus Pocillopora as well as large colonies of Porites [26] in French Polynesia, with temperatures above 29.5 °C for several weeks. The effects of TOHS on coral are complex and depend on various factors and communities. In addition solar radiation levels were recorded to be higher [28]. Subsequently, in 2005, NOAA [29] reported a large-scale climate anomaly, which occurred throughout the Caribbean Arc. This phenomenon was particularly intense in Guadeloupe but less so in the Gulf of Mexico.

The SST anomaly certainly ever recorded [30] which is characterize by the exceptional TOHS season of 2005 represents the most visible sign of climate change and is one of the most destructive effects of rising SST. It had a direct long-term effect on marine life in the Caribbean. This phenomenon caused the bleaching of about 80% of corals in 2005 and the death of 40 to 50% of corals in Guadeloupe. Corals, particularly Porites, are outstanding indicators of climate; they are also extremely precise tracers that have long demonstrated their effectiveness in reconstructing climate change, [31]-[32]-[33].

They are however very sensitive to water temperature and acidification [34]. The stable carbon and oxygen isotope studies isotope studies were focused on tropical corals and one bivalve collected in the Caribbean, more precisely in the fringing reef of the Guadeloupe marine reserve, "The Heart of Marine Park," removed from sources of anthropogenic pollution [35]. The isotopic studies (of two scleractinian which survived the hotspot) (*Pinna carnea*) were carried out using a mass spectrometer at the Paleoenvironment and Paléobiosphère Laboratory of Lyon-1. Thanks to the *Porites Divaricata*, which has long been used as an indicator of climate, it was possible to go back to 2002.

III. The Area of Study, Guadeloupe Archipelago

Samples that have led to these data were collected in August 2009 in Guadeloupe at the Grand Cul-de-Sac Marin coral reef in Guadeloupe archipelago (16 ° 15 'N, 61 ° 33 O). We selected common animals whose particularity is to record the environmental and physiological changes in their carbonate structure ($CaCO_4$), such as corals of the family *Divaricatas Porites*, *Millepora* [36]. Both corals grew in close proximity to each other at an approximate depth of 6 meters.

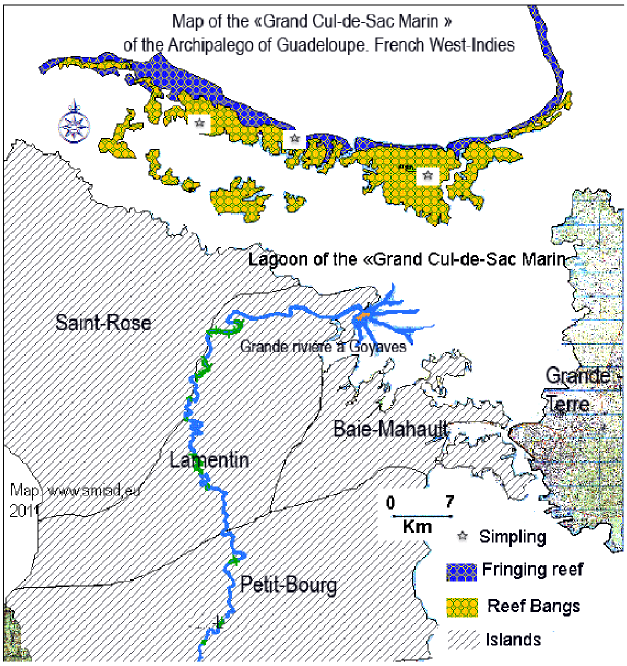

Fig. 3 Part of Guadeloupe island and the site where the three animal species (The Millepora Alcicornis, the Porites Divaricata, and the Pinna Carnea) were taken in "Grand Cul-de-Sac Marin". Siméon, 2010

Certain particularities and vulnerabilities of these animals have already been the subject of numerous studies. Indeed, the reduced growth rate and the calcification process, caused by strong thermal stress or bleaching, are well documented [37] [38]-[39]. It was found that isotopic changes occurred in the coral skeleton, notably due to the decrease in both $\delta^{18}O$ and $\delta^{13}C$ values of the skeleton after bleaching [40].

A. Presentation of Samples

Due to ecological concerns and because of the significant surface area of lost coral reef after the 2005 Ocean Thermal HotSpot, for this first studies three healthy samples was collected, one "*Porites Divaricatas*, one *Millepora Alcicornis* and one *Pinna Carnea*." It will help us understand how the marine life of Guadeloupe, whose coral reefs are similar to those of other Caribbean islands [41], experienced the 2005 TOHS.

Porites Divaricata*: Porites Divaricata* is the species most commonly used for references in Paleo SST (Sea Surface Temperature) because of the robustness of its oxygen isotope composition [42]. Corals are known to be difficult to identify and it is usually from the morphology of the Porites skeleton that this species is recognized. Its elasticity depends on the growth medium and many other factors, the most common of which are light, temperature, turbidity [43], transparency and sea water salinity. Porites are part of the most surprising species and are the most complex due to their rich diversity; thus it is a challenge for logical classifications [44]. It is also the most abundant and remains an essential component in the balance of coral reefs, whose taxonomy (taxonomically) stimulates reef development. Porites are more resistant to process of diagenetic alteration than most other species of coral - such as Acroporas whose jaw is thicker - which allows them to be more resistant to thermal shock [45].

The Millepora: *Millepora* is a scléractiniaire, a symbiotic coral which bind to an alga of the family of "dinoflagellés", a symbiotic relationship. Although this relation is not yet well understood and it's subject to many interpretations [46]. It is is known that this cohabitation allows a contribution to the host (coral) out of oxygen and offer with the support (the alga) the elements necessary to photosynthesis. Moreover chemical exchanges between the host and the symbion seem to help to support an acclimatization which is carried out by the means of a process of selective natural adjustment of the coral to the abrupt changes of temperatures [47]. *Millepora* is considered more as a false coral because of its dependence to a symbiotic alga, contrary to Porites which is a true coral.

The Pinna carnea: The space of distribution of *Pinna Carnea* relates to a geographical zone ranging between the south of Florida to Brazil [48] in the habitats of underwater herbaria [49]. Few studies were carried out concerning this animal species. The bivalve (fig. 4) which is part of the family of Pinnidaea taken at the base of a mangrove (palétuvier) was approximately 0.5 cm under water in a coral reef. Pinna Carnea is a sessile bivalve, very specialized in the family Anisomyaria [50].

All results of the isotopic studies will be shown, however, considering that only the Porites allowed to go up until 2005 it will to be the principal indicator of this paper.

B. General Characteristics of the Porites

High average temperatures of sea water +32°C in 2005 (NOAA) was one of the most violent external causes of coral bleaching, while normal average temperatures for tropical corals, 25°C to 29°C, promote growth and optimal calcification of tropical corals [51]. Corals do not all have the same tolerance to high temperature thresholds, around 30°C to 32°C, like most Scleractinia. One characteristic of Porites is its mechanical properties, whose great resistance comes from its high level of aragonite, which makes up the skeleton; while calcite, of which the bulk of most mollusk shells is composed [52], has reduced mechanical properties [53].

The first environmental factor responsible for massive bleaching is therefore the increase in SST temperature. Other factors are the active photosynthetic radiation insolation (PAR, 400-700nm) and ultraviolet radiation (UVR, comprise between 280-400 nm) [54]. However, it has been shown that a lack of sunlight can also cause coral bleaching and the $\delta^{13}C$ values allow estimates of variations in luminosity [55]-[56].

Fig. 4 Sample of Porites Divaricatas *Millepora Alcicornis* and *Pinna Carnea* of Guadeloupe. Siméon, 2011

C. Method of Isotopic Studies

The use of the oxygen isotope thermometry based on biogenic carbonates in the reconstruction of sea water thermal variations has long been demonstrated and is widely accepted [57]-[58]-[59]. Isotopic analyses were performed using a mass spectrometer at the Laboratory of Paleoenvironment and Paléobiosphère, Lyon 1. Oxygen isotope compositions of water samples reflect the regional budget between the rates of evaporation and precipitation.

To do this, we used the equation to balance the seawater $\delta^{18}O$ Seawater (‰, VSMOW) = 0281 X Salinity - 9.14.

The method of $\delta^{13}C$ analysis in calcium carbonate derives from McCrea [60]. Weber and Woodhead [61] have shown that the scleractinian skeleton isotopic composition variation was mainly due to SST. However, no causal relationship has been demonstrated between growth rate, $\delta^{13}C$ and temperature. A study [62] has demonstrated a positive relationship between insolation and scleractinian skeleton δ13C values concerning CO_2 splitting during photosynthesis by symbiotic algae in many corals. A laboratory experiment, Weil *et al*. [63] also showed that the coral skeleton $\delta^{13}C$ values were good indicators of changing irradiation. Metabolic splitting is essentially what influences the d13C skeleton [64]-[65]-[66]. As it is for the $\delta^{18}O$, the international reference is the PDB (Pee dee Belemnite ‰). The isotopic composition of carbon $\delta^{13}C$ represents the relation between the heavy isotope $\delta^{13}C$ and the light isotope $\delta^{12}C$. The zooxanthellae coral skeleton $\delta^{13}C$ nevertheless manifests a real paleo-environmental signal via the precipitation process of extracellular fluid that occurs between the skeleton and the tissue that covers the coral.

TABLE I
TAXINOMIC TABLE OF THE CORALS AND THE BIVALVE

Family	Order	Genus	Deep (m)	VPD Mean d18O	Mean Temperature (C°)	Mean d13C	Mean AER (mm/y)
Poritidae	Scleractinia	Porites Divaricatas	6	-4.62	30.3	-3.99	17.6
Milleporidae	Capitata	Millepora Alcicornis	6	-1.65	29.48	0.129	*
Pinnae		Pinna carnea	0.05	-0.69	28.7	1.70	*

The fluid $\delta^{13}C$ used during calcification reflects both the seawater δ13C and a combination of the metabolic processes, including photosynthesis and respiration in the tissue of the coral [67]-[68]. Isotopic measurements of $\delta^{13}C$ provide information on two major sources of carbon: metabolic CO_2 resulting from coral breathing [69] and sea water CO_2 originating from atmospheric CO_2 by absorption, thus contributing to the process of biomineralization. The average proportion of rain carbon ($C.org_{(1000m)}$: C.carbonate) in the tropical and subtropical Atlantic is 1.8 [70], which further increased the similarities between the current water masses circulating from the Lesser Antilles to the Gulf of Mexico.

IV. RESULTS

A. The Temperatures

Stable isotope measurements of coral skeleton $CaCO_3$ reveal significant variations in the $\delta^{13}C$ and $\delta^{18}O$ values of the aragonite. $\delta^{18}O$ measurements provide information on temperature and the technology is highly documented by Weber, et Woodhed ; Kawahata *et al*, Corrège. Corals also provide information about atmospheric, chemical and physiological disturbances caused by the environment. Porites have a significant capacity to adapt to high temperatures for short periods [75] however, the tolerance threshold of these animals in the wild has not been documented in a systematic way. The high resistance of Porites was attributed to its slow metabolism and low growth rate [76], which makes this species less vulnerable to bleaching and change in their environment.

The equation used to determine the variations in temperature of coral (T) of $\delta^{18}O$ (dc) recorded Porites divaricatas (Poritidae) during the calcification of the skeleton is:

$$T(C°) = -5.38(\delta c - \delta w) - 1.08 \quad [77]$$

Fig. 5 presents $\delta^{18}O$ and $\delta^{13}C$ (‰ PDB) of Porites divaricata, Millepora alcicornis and Pinna carnea. The temperatures are indicated, however only the Annual Extension Rate (AER) of the Porites is represented because its characteristics are widely informed. Pee Dee Belemnite is a standard isotopic reference of reports of the oxygen and the carbon.

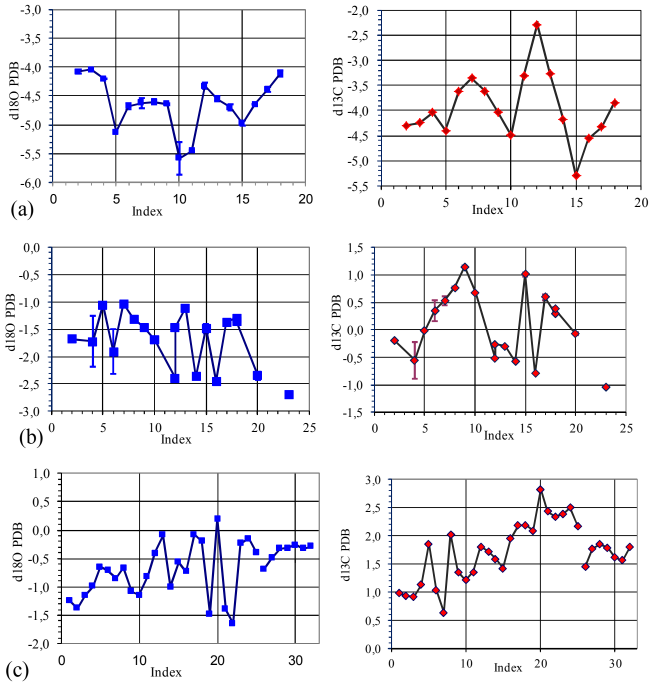

Fig. 5 variations in the $\delta^{18}O$ (‰ PDB) (left column) and $\delta^{13}C$ (‰ PDB) (right column) values of *Porites divaricate* (a), *Millepora alcicornis* (b) and *Pinna carnea* (c) as a function of coral growth. Increasing sample numbering indicates ageing (biological time) of corals. Samples were taken according to a 0.5 mm interval

The temperature of the salt water of Guadeloupe Archipelago as well the fresh water (tab.2) was calculated by measuring the $\delta^{18}O$ of five water samples. The first three data are from the salt water toke in different depth from the coral reef to the fringing barrier off the Atlantic Ocean. The fourth other data are from the fresh water toke in the bigger river of the Archipelago "Grande Rivière à Goyave", from the city of Goyave to the top of the mountain. The mean temperature of Guadeloupe Archipelago was estimate to 29°C.

TABLE II
SEA AND FRESH WATER CHARACTERISTICS OF THE CARIBBEAN ISLAND GUADELOUPE. (GPE=LAGOON, GOY= GOYAVE GREAT RIVER)

Name	$\delta^{18}O$ (SMOW)$_{ve}$	δD_{ave}
Gpe 6m-v53	1.05	1.7
Gpe 5m-v55	1.18	3.7
Gpe 5m-v57	1.36	4.9
Goy 1m-v2	-2.21	-5.1
Goy 0.05m-v6	-1.68	-2.7
Goy 0.05m-v8	-1.98	-8.1
Goy 0.05m-v11	-2.34	-2.6

The means of temperature between the corals are low ~1°C and near 2°C compare to the bivalve. Figure 6 shows the average change in surface temperatures in Grand Cul-De-Sac Marin (Guadeloupe) obtained from isotopic analyses performed on *Porites* from January 2002 to 2009 and Millepora from November 2005 to May 2009.

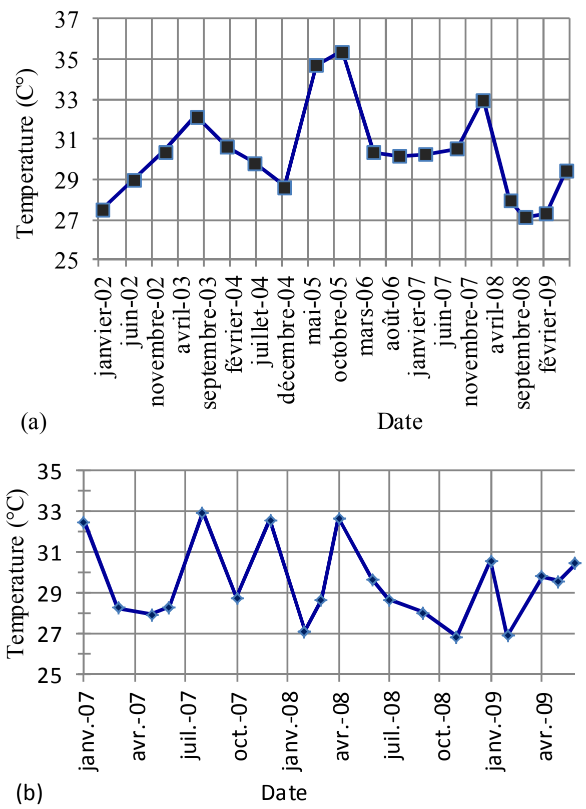

Fig. 6 variation of the average temperature of the two corals, the *Porite* (a) from 2002 to 2009 and the *Millepora* (b) from the end November 2005 to 2009

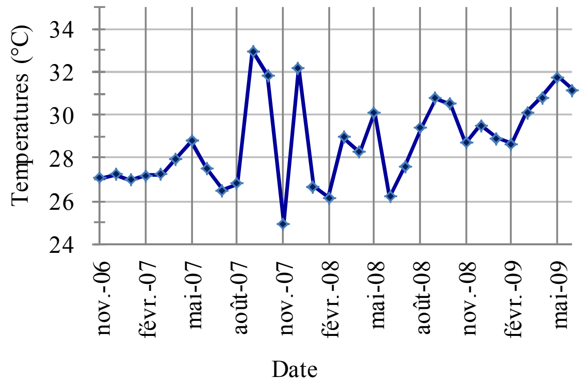

Fig. 7 Variation of the average temperature of the bivalve, *Pinna carnea*, from end 2006 to 2009

The isotopic measurement of the *Porites* shows that higher than expected temperature extremes were reached, up to a maximum of 35.5°C in October. So in August 29, average SST temperatures were near 35°C in the Caribbean's area concerned by the TOHS. Must higher than the NOAA satellite data recorded. Again in September, when Hurricane Rita hit New Orleans and South Texas on the 24th, higher temperatures were still present in the Caribbean.

B. Relationships between the Atmosphere and the Ocean Using Isotopic Data

The main factor controlling the skeleton 13C is linked to photosynthetic activity, which is itself sensitive to solar radiation [77]-[78] that is believed to be identical everywhere on the globe [79]. We saw earlier that great temperature values were recorded by *Porites* in 2005 which do not exactly correspond to the data obtained with the Radar Altimeter System Database. Consequently, we became interested in the $\delta^{13}C$ signal to obtain further information on factors that influenced climate change in this region in 2005. To identify the nature of the signal recorded by the $\delta^{13}C$, calculations were done to determine the "Annual Extension Rate (AER)." $\delta^{13}C$ calculation methods are still being debated. However, there is an equation allowing to calculate the *Porites'* AER using the equation:

13C AER (*regression equation*) $\delta^{13}C = -0.140\ AER - 1.53$, with $R2 = 0.35$ ($P < 0.01$)

These values are used to measure the intensity of the regression (relationship between X and Y). The $\delta^{13}C$ is a good indicator of dissolved inorganic carbon "DIC" (Dissolved inorganic carbon) in seawater [80]. Given that $\delta^{13}C$ reflects the metabolic activity of symbiotic algae (zooxanthellae), negative $\delta^{13}C$ values mean a decrease in symbionts' photosynthetic activity. This decrease may be caused by a decrease or increase in temperature or a decrease or increase in the plankton stock - depending on the increase or decrease in temperature/light factors. The wintering period from October 2004 to May 2005 shows a significant drop in biological activity near 5.00 AER in *Porites*, then a substantial, yet steady increase between December 2004 and January 2005.

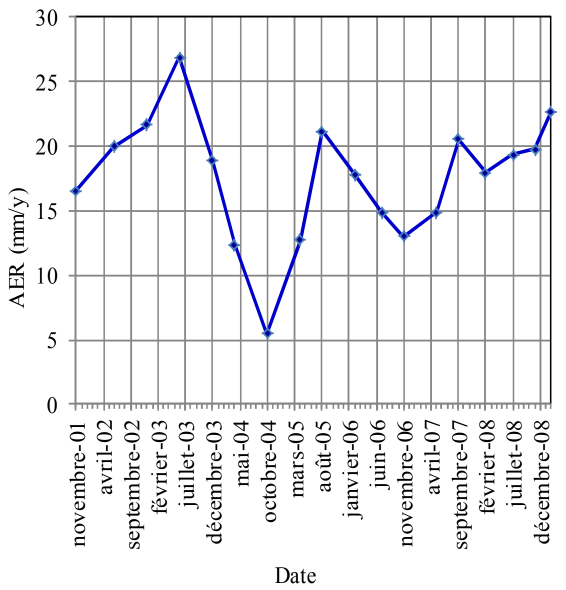

Fig. 8 Annual Extension Rate (AER) from 2002 to 2009 of the *Porites* estimated in mm/years

The measurements obtained by the *Porites* $\delta^{13}C$ since 2002 (Fig. 8) show large and sharp fluctuations with a stabilizing trend as of 2009, then rising again in mid-2009.

The comparison between $\delta^{18}O$ and $\delta^{13}C$ measurements help to understand the interaction between temperature raise and lights during TOHS phenomenon. The $\delta^{18}O$ values shows that at the beginning of January 2002 the temperatures were lower by nearly two degrees than normal and rising to >36°C in 2005. They fell again in late 2008 to an extremely low level, slightly above 26° C. The $\delta^{13}C$ indicates that in mid-2003, the physiological activity becomes greater. High temperatures in this period exceed 32.5°C causing a significant drop in physiological activity, approaching 5.00 AER in December 2004, with values of normal average temperatures of 29°C. Subsequently, physiological activity accelerates to exceed 20.00 AER indicating good metabolic activity. Since the average water temperature is between 27 and 29 ° C, it's possible to deduce that the ratio at equilibrium of the Annual Extension Rate of 20.00 EAR, is related to the temperature value of 29°C with an average solar radiation normally tolerable between 6 and 6.50 kWh / m² / day at 6 m depth (depth of coral sample) in clear and healthy water.

The adaptation capacity of corals, particularly Porites, to live in environments where the level of solar radiation can increase significantly from -280 to 400 nm- [81] can be explained by the use of a molecule called "mycosporine" (like amino acids MMAS) that allows it to protect, regulate or heal itself. The relationship between the concentration of MMAS and UVR doses are well correlated [82]-[83]. This means that as a result of intense solar emission, there is rapid reaction to decreasing AER, then a gradual increase to an acceptable average associated to a return to normal. As noted earlier, solar radiation plays a significant role in climate change [84] at these latitudes. Since metabolic processes linked to coral breathing depend on the season winter / summer [85], and given the proven relationship between coral skeleton $\delta^{13}C$ and insolation, we can estimate the amount of solar radiation received by the aquatic environment by measuring the rate of annual growth (*Extension Annual Rate*). On the coast of Guadeloupe seasonal winter values (fig. 9) greater than 7.50 kWh / m² / day were thus measured in May 2005, with a fall of just over 5.00 kWh / m² / day in September. This information provides an indication of the level of solar radiation emissions received by the animals in the Lesser Antilles at a depth of 6m (*depth of coral samples analyzed*). Knowing that solar radiation had an influence on *Porites* metabolism thereby demonstrating that the emissions were massive research was conducted to find out the variations in Guadeloupe. Thus, by studying the data of "Monthly Averaged Insolation Incident On A Horizontal Surface" of NASA [86], significant phenomena were observed in the region of the Lesser Antilles - lat.15 ° N, long.61 ° W. Values in the Lesser Antilles (fig. 9)., has been a steady increase in emissions of solar radiation since 1984. Fortunately, values available by NASA in the Monthly Averaged Insolation Incident on a Horizontal Surface stopped in 2005.

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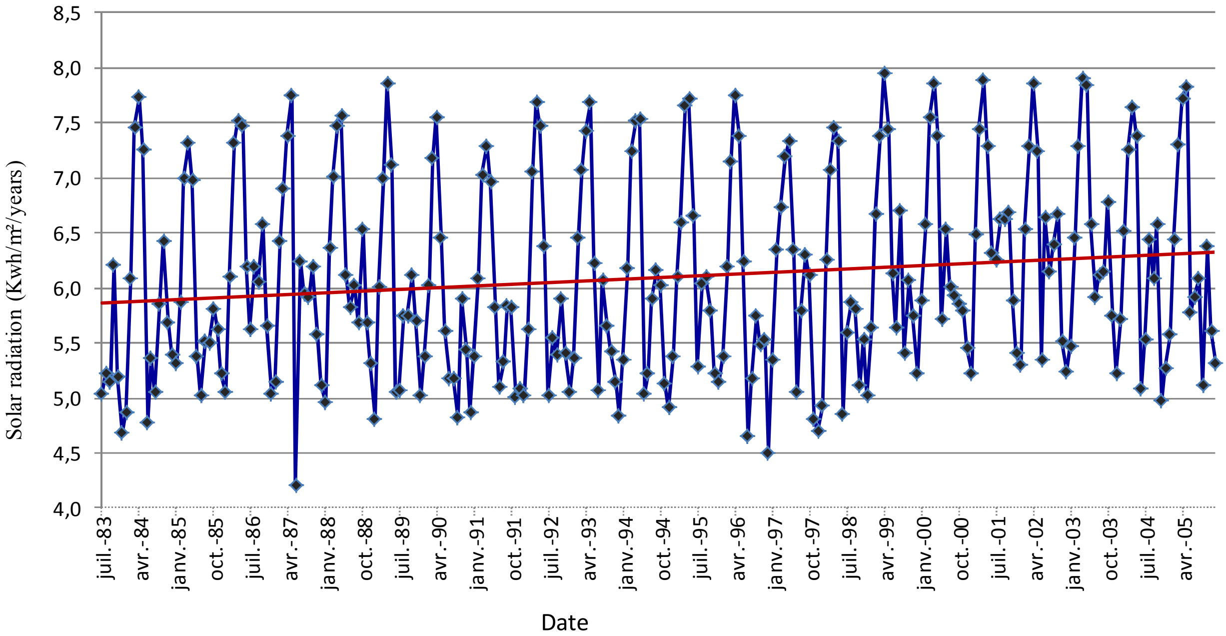

Fig. 9 Solar Radiation average in the Lesser Antilles from 1983 to 2005. Siméon 2012, data NASA

V. Hurricane Katrina

A. Design of Hurricane Katrina

Recent studies have shown that hurricanes of category 3 and above on the Saffir-Simpson scale were particularly sensitive to the rise in sea surface temperature (SST) due to climate change [87]-[88]. The atmospheric conditions described [89] indicate that there was a high over the Gulf of Mexico, characterized by temperature conditions of high SST, which led to the intensification of Katrina which was at category 3 and losing power on August 26. This low pressure system continued to grow on August 27 carried by hot winds from the north between the east coast of Morgan City to the coast of Alabama. On 28 August it reached category 5 with winds of 160 mph and a pressure of 908 millibars. Pan and Wu [90]-[91] have estimated that an 8% growth in hurricane intensity corresponds to an increase of 1° C of SST. Based on DHW information, Eakin *et al* [92] were able to establish a link between this unusually warm period from June to October 2005 and the hurricanes that passed in the Gulf of Mexico, Katrina, Rita, Wilma.

B. Influence of physic forcing on Katrina

As already mentioned, for a hurricane to form, it is necessary that SST be above 26° C down to a significant depth [93]. The formation of cyclones and hurricanes reacts to, among other things, the Coriolis force, water temperature and the absence of wind shear. Since the Coriolis force is weak at the equator, hurricanes form more easily between 10' and 35' latitudes, where water temperatures are also warmer.

In addition, during the period covered by the TOHS (*August-November 2005*) atmospheric forcing, in the form of established phenomena, occurred in the Gulf of Mexico.

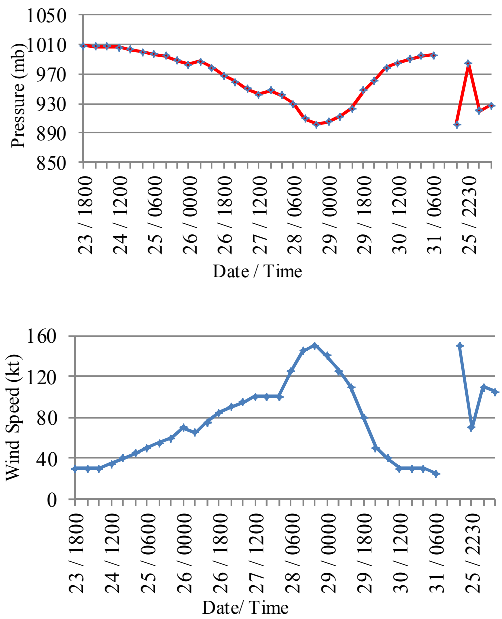

Fig. 10 Comparison between Hurricane Katrina Pressure (mb) and Wind Speed (kt) Sources: Tropical Cyclone Report Hurricane Katrina. 23-30 August 2005 Richard D. Knabb, Jamie R. Rhome, and Daniel P. Brown National Hurricane Center, 2005

TABLE III
WATER MASSES OF THE CARIBBEAN SEA AND GULF OF MEXICO (USA)

	Eastern Caribbean1			Eastern Gulf of Mexico2				Western Gulf of Mexico3			
Water Mass	Depth m	σ kg/m^{-3}	Feature	Depth m	σ kg/m^{-3}	Feature	Range	Depth m	σ kg/m^{-3}	Feature	Range
SUW-LC	150-250	25.4	S_{max}	150-250	25.4	S_{max}	36.7-36.8				
SUW				150-250	25.4	S_{max}	36.4-36.5	0-250	25.4	S_{max}	36.4-36.5
18°C W	200-400	26.5	$O_{2\ max}$	200-400	26.5	O_{2max}	3.6-3.8 mL-L^{-1}				
TACW	400-700	27.15	$O_{2\ min}$	400-700	27.15	O_{2min}	2.85-3.25 mL-L^{-1}	250-400	27.15	O_{2min}	2.5-2.9 mL-L^{-1}
AAIW	600-800	27.3	NO_{3max}	na	na	NO_{3max}	na	500-700	27.3	NO_{3max}	29-35 µg-at L^{-1}
AAIW	700-900	27.4	PO_{4max}	700-900	27.4	PO_{4max}	1.8-2.5-µg-at-L^{-1}	600-800	27.4	PO_{4max}	1.7-2.5 µg-at L^{-1}
AAIW	600-900	27.4	S_{min}	800-1000	27.5	S_{min}	34.86-34.89	700-800	27.5	S_{min}	34.88-34.89
AAIW	800-1000	27.5	SiO_{3max}		27.5	SiO_{3max}	*		27.5	SiO_{3max}	*
UNADW	1100-1600	27.7	S_{max}								
	at still	27.75	SiO_{3min}								
	at still	27.75	PO_{4min}								
	at still	27.75	NO_{3min}								
MIW**				900-1200	27.5	SiO_{3max}	23-25 µg-at-L^{-1}	1000-1100	27.5	SiO_{3max}	24-28 µg-at L^{-1}

Sources : Morrison and Nowlin 1982; Nowlin and McLellan 1967; Morrison and Nowlin 1977; Nowlin and McLellan 1967; Morrison *et al*, 1983; -na= data not available for study. SUW-LC = Subtropical Underwater in the Gulf but outside the Loop Current; 18°C W= 18°C Sargasso Sea Water; TACW = Tropical Atlantic Central Water; AAIW = Antarctic Intermediate Water; UNADW = Upper North Atlantic Deep Water; * *MIX = Mixture of low silicate UNADW and very high silicate Caribbean Mid-Water; *high SiO3 in AAIW and MIX waters results in broad SiO, maxirnurri approximately from 27.50 to 27.70. Source, MMS US Department of the Interior. Mineral Management Service, Gulf of Mexico OCS region, 2000

The Fig. 10 shows the correlations between atmospheric pressure measurements and wind strength during the development of Hurricane Katrina, from August 23 to August 29, 2005. Firstly, it is evident that the lower pressures are in connections with the stronger winds. Secondly, the graphs clearly show significant peaks on August 27 and August 28 from at 12 o'clock to 0000 o'clock 2005, the pressure was almost 940 mb with winds at 100 km / h and subsequently 900 mb with winds over 140 km / h on August 28 still 0000 o'clock in the night. Other extreme conditions reigned in the Gulf Coast during this period, like warm water coming from the Caribbean current (CaC).

C. Water Mass Exchange between the Caribbean Sea and the Gulf of Mexico

Since salinity plays an essential role in the ability of seawater to transfer energy and provide thermohaline circulation, we sought to determine if there are chemical similarities between the Caribbean Sea and the Gulf of Mexico. Sea water surface salinity in the Gulf of Mexico is generally between 36.0 and 36.5 5 [94].

Nowadays, upper columns of certain southern Caribbean waters are composed of a certain amount of fresh water "CW, 0-80m" and show high levels of salinity in the bottom layer of subtropical water "SUW, 80-180m;" this forms the permanent thermohaline circulation of the Caribbean [95]. However, it was noticed that today SUW salinity is higher by 1 unit than CW salinity [96]. Caribbean Sea and Gulf of Mexico water masses are quite similar (tab. 3), which facilitates the transport of energy laden waters of the Caribbean to the Gulf of Mexico. However, surface water of low salinity was measured by Schroeder et al., <36 between Texas and Louisiana <33 between Louisiana-Mississippi-Alabama, from the Mississippi River and the Atchafalaya [97] coming certainly from the river current of the North Atlantic (NeC)

D. The Loop Current Effect

Powerful ocean currents regulate the dynamics of marine waters flowing through the Gulf of Mexico. The figure 11 shows the Loop Current which is a branch of the western This The figure 11 show the Sea Surface Heating Anomaly (SSHA) data obtained from the Radar Altimeter Database System (RADS) maintained by the Delft Institute for Earth-Oriented Space research (DEOS). The mesoscale variability connection between the tropical Atlantic, the Caribbean Sea and the Gulf of Mexico has been demonstrated by Murphy et al.'s oceanic modeling [98]. It is believed that the Loop Current affects hurricanes and their trajectory [99]. The energy-laden waters of the Lesser Antilles carry this load by way of the Caribbean Current (CaC) to the Gulf of Mexico [100]. Generally, during a tropical depression, winds at the periphery of the phenomenon causes the mixing of waters, than the warm surface waters are cooled by deep water swirls. In August 2005, the water had a uniform temperature well above 26°C down to a depth of several tens of meters, so the cooling did not occur.

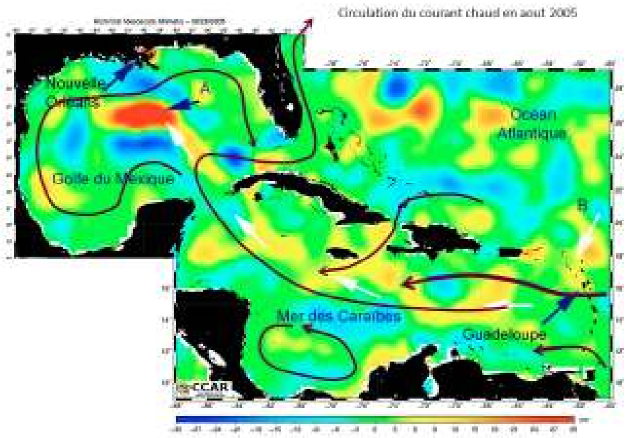

Fig. 11 North Atlantic Current (NEC) through the Caribbean's to the Gulf of Mexico on August 28, 2005. Source CCAR, Colorado Center for Astrodynamics Research

Murphy *et al*. have shown that this current (*anti-cyclonic*) forms first in the Caribbean, due to, in part, potential vortex advection in the Atlantic, then flows through the Caribbean along the corridor guiding it to the Gulf of Mexico via the Yucatan Channel. Then it goes to the Florida Straits where it meets the Gulf Stream. The Caribbean current (CaC) that enters the Gulf of Mexico through the Yucatan Channel create some eddies called Loop Current Eddies, (LCEs) and its driven by a very complex process [101]. The Caribbean Current is crucial to the Gulf of Mexico [102] because its plays an important role in the transfer of heat and salt in the high northern latitudes CW. It also constitutes the main current as well as the main energy source circulating in the Gulf of Mexico [103].

VI. Interpretation

The complex genesis of Katrina involved the interaction of tropical wave, the middle tropospheric remnant of Tropical depression Ten, and an upper tropospheric trough [104]. Recent measurements obtained from mass spectrometric studies on corals to better understand TOHS, in conjunction with historical events related to the Katrina phenomenon allow to better assess the magnitude of stress sources and the variety of factors that came into connection. We were able to highlight the following the role of TOHS in the Caribbean: energy heating, solar radiation emissions (*sun light*), water vapor and the role of the water currents. Hurricanes arise from the instability of the ocean-air relationship. A temperature above 26°C SST produces elevated evaporation that influences air-ocean exchange, due to the increased moisture in the air which allows the formation of hurricanes [105].

These extreme conditions of warming ~35°C caused sea temperature rise and provoked many water vapor with intense solar radiation in August 2005 on clear water. However the hurricane Katrina at "Depression Ten" scale (*13 to 19 August 2005*) was certainly not strong enough to absorb the wall critic masses of disturbance and dissipated. At the limit of the TOHS, this "Depression Ten" recovered its potential using one part of the critic masses of the TOHS. From August to end September 2005, water masses transported by the sea currents, at relatively shallow depths, remained warmer than what is suggested by satellite data, preventing the layers from cooling [106].

Are represented the influence of the Solar radiation, Solar heating, Water vapor and the Clouds. From August 13, 2005 with a pressure of 1008 mb, still August 18, 2005, the disturbance Katrina was visible. But when its move in the area concerned by the TOHS, the intensity of the phenomena dissipated. Later, near Cuba, 23 August, it's was observed as Tropical depression named Katrina moving slowly to Florida.

VII. Conclusion

This paper is a first step to analyze the implications of Thermal Ocean HotSpot on tropical cyclones and Hurricanes. More isotopic studies combine with satellite data are necessary to get more precisions in the measures to better estimate the evolution of the Hurricanes in the future, because both techniques have their limits. However to better estimate the changes more factors has to be take in account by the models, twice environmental and anthropogenics and depending of certain conditions or situations. What could occur in a scenario where one hurricane of category 3 on the Saffir-Simpson scale meets one medium or important TOHS (like in 2005) in the Caribbean or the Gulf Coast Basin ? The phenomena of TOHS of 2005 was not isolate because it concerned the wall world in all oceans still Pacific, Arabic, Russia, Canada and Greenland. In view of the circumstances that 400 million peoples are living on coastal areas [107], the combine effect of sea level raise, hurricanes and anthropogenic impacts (*like the common oil spill in the Gulf Coast*) in a context of TOHS could provoke major natural hazards.

Beyond the scientific considerations, the most difficulty by many scientists to model climate change scenarios come from partisan choices of their sector than to take in account the uncertainties and their incapacity to investigate new ways and new approaches. TOHS study is at its beginning and multidisciplinary approach could offer more efficiency. One first stapes of international cooperation was engaged in this direction since the adoption in December 2006 of a United Nation Resolution titled "Toward the sustainable development of the Caribbean Sea for present and future generations" in the aim to better understand the connections between factors impacting on the climate and the marine ecosystems from the Caribbean's to the Gulf Coast and the economic, ecologic, cultural implications.

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