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Is it Possible to Weaken a Hurricane? Sketch of a Solution Using the Locally Available Energy

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Abstract

The grandiose but formidable meteorological events known as tropical cyclones, hurricanes or typhoons are primarily caused by an excessive rise in the surface temperature of tropical seas during the hot season. Too large a temperature disequilibrium between the ocean surface and the upper atmosphere can first transform a tropical depression into a tropical storm, then into a hurricane when the system meets a bifurcation and crosses a more or less chaotic zone.

Recent developments in non-linear thermodynamics and in the physics of chaos show that order appears, characterized by an eye and its wall of clouds, when a tropical storm turns into a hurricane. The system self-organizes and then becomes a gigantic thermal power plant, mobile on the surface of the ocean, that uses its motive power to develop even further.

The situation is, in many respects, similar to that of safety valves in which order appears in the form of self-organized supersonic flows that interfere violently with the structures. In both hurricanes and valves, this emerging order is harmful because it hinders the necessary dissipation of energy.

The aim of this article is to outline a possible solution to destroy this order contained in a hurricane in order to weaken it by downgrading it to a tropical storm.

Keywords: chaos, tropical cyclone , disorder, entropy, order, dissipative structure, thermodynamics, vistemboir.

1. INTRODUCTION

Extremely violent and devastating tropical cyclones are attentively observed by ocean science specialists who can now predict their short-term trajectory [1][2]. The evacuation of millions of people is sometimes necessary; this massive exodus causes huge disarray and catastrophic situations. Hundreds of thousands of people are forced to seek shelter as best they can.

The damage is considerable.

> What can be done about it? Nothing, we are told. Isn’t there, at least, the beginnings of a solution?

Let us go back, without any preconceived ideas, to the roots of the problem in the field of energetics.

Situation update

The hurricanes of the North Atlantic Ocean will serve as our guiding principle; the concepts developed can be transposed to other ocean basins.

The "*Great Hurricane*" of 1780 was one of the most devastating in history. Between 20,000 and 30,000 people lost their lives. Hurricanes today are less fatal because the surveillance, warning and prevention systems have developed considerably, but they still cause enormous material damage.

For the USA alone, the average annual damage since the beginning of the twenty-first century amounts to some 40 billions US dollars/year. The hurricanes of 2017 were particularly active; the damage caused is officially estimated by the United States government at more than 300 billions US dollars.

For comparison, the cost of a 1000 MW power plant is about 5 billions US dollars. These figures give pause for thought. The cost of hurricane-related disasters for 2017 and for the USA alone thus corresponds roughly to the price of sixty 1000 MW power stations, which represents, for example, the entire French nuclear fleet.

It is said that the power of a hurricane is equivalent to that provided by hundreds of high-power electric power plants (for example, four hundred 1000 MW power plants operating at nominal speed).

With current global warming, we must consider a possible increase in the harmful effects of these tropical cyclones. Some predict that they will be more numerous and others that they will be more violent.

It might be time to ask the following question about hurricanes: Couldn’t the colossal sums spent every year repairing the damage created be better used to control these hurricanes in order to reduce their aggressiveness? And is this possible using current technologies?

Some attempts to fight hurricanes

The work undertaken, to date, to combat hurricanes has not been conclusive because it failed to establish a sufficiently significant power ratio to meet this challenge. Some of these projects should not have been abandoned so quickly.

Tenacity in research is a virtue!

Let's mention some of these attempts:

- Dispersion of chemical products in the clouds,
- Installation of gigantic funnels to cool the water by diverting hot water currents,
- Dry ice blasting,
- Seeding the clouds with silver iodide,
- Dropping a nuclear bomb in the hurricane - no comment!
- Flying through the hurricane in supersonic aircraft,
- Cooling the waters with nitrogen,
- Using very large submarine pumps,
- Laser treatment or microwave diffusion from space.
- etc.

What we think of these attempts . . . in no particular order

"*These scientific dreamers have tried everything to eradicate cyclones.*"

"*These are such powerful weather phenomena that direct action is impossible.*" "*However other professors, who can be described as gentle dreamers, or unconventional inventors, continue to want to attack cyclones at their roots.*" "*There are some crazy attempts but that were initially designed as very serious projects.*"

"*On the other hand, several patents propose to prevent their formation, by pumping cold water from the depths towards the surface of the oceans. But the catch is this … Eliminating cyclones would require a very significant cooling of the tropics, which would also have consequences on the global climate …*"

"*The only thing left is to barricade ourselves.*"

etc.

In short, governments seem to have given up any idea of solving the problem in favor of observation and prevention only.

In this gloomy context maintained by these despairing commentators, I personally believe that an outline of a solution can nevertheless be presented and subjected to criticism.

Hurricanes bring some signs of hope

Among all this bad news, there are nevertheless some hopeful signs. The main thing is that a hurricane can downgrade itself to a tropical storm depending on the weather conditions it encounters over the ocean during its journey. Through not a general rule, this encouraging aspect deserves to be highlighted.

For example, Hurricane Florence, which developed over the North Atlantic Ocean in the summer of 2018, was detected on August 29 in a calm period. This suspicious area near the coast of Africa was then monitored by meteorologists. It became an organized tropical system, then a hurricane in early September (Figure 1).

After weakening into a tropical storm, Hurricane Florence then gathered strength again due to, among other things, warm waters and low wind shear.

Another positive aspect is the speed of a hurricane (about 25 km/h), which allow to follow its movement.

Knowing how a hurricane reacts to its environment is a valuable lesson that we owe to meteorologists equipped with increasingly powerful and reliable observation tools.

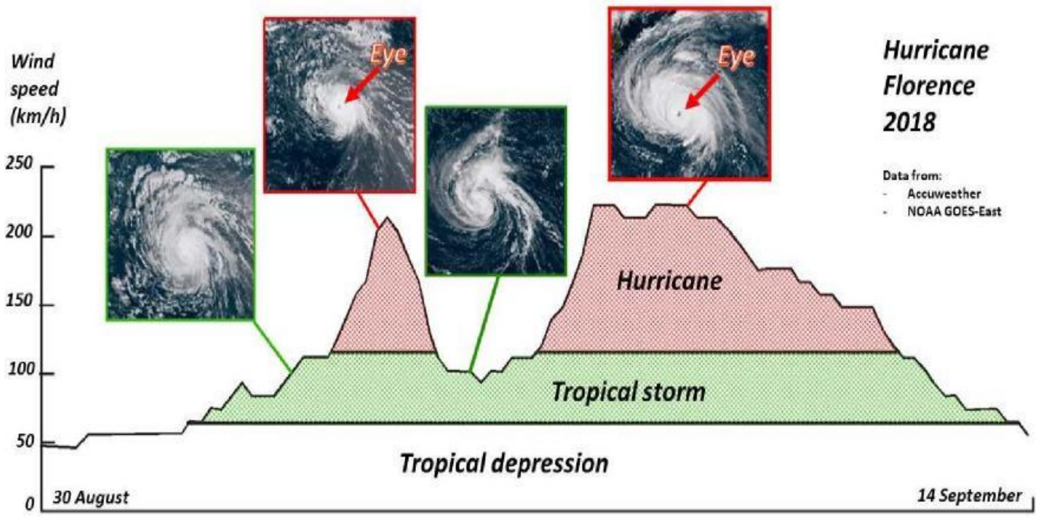

Figure 1: Behavior of hurricane Florence during the summer 2018

The hurricane: a particular kind of valve

A hurricane acts like a valve, releasing the thermal energy accumulated under the Tropics during the hot season.

Valves, especially safety valves, are a trap set by physics. These safety valves rarely open, but when they open suddenly, they must quickly dissipate a considerable amount of energy [3]. Accidents due to valves are numerous and disastrous because they are all subject to the maxim:

“***A faucet is only simple when it is closed.***”

In the field of large electric power plants, the difficulties encountered in the operation of valves were considered unavoidable evils in the 1980s. It was even taught that the dissipation of a few tens of megawatts in a control valve regulating the inlet pressure to the turbines was impossible without vibration and noise.

The difficulties became more acute with the commissioning of nuclear power plants which make use of high unit power machines. Huge valves adapted for large volume flows must, at partial loads of the machine, quickly dissipate tens of megawatts.

Statistics published on power plant capital assets showed the importance of these valves. Manufacturers and users experienced serious difficulties, in particular due to the rupture of valve stems. Other industries using valves experienced substantial damage or major accidents. For example, ships had to turn back for long and costly repairs to a safety valve.

It was not therefore possible to eliminate the dangerous and random functioning of valves. And yet, this was achieved in 1984 by using the principle of worst action [4][5][1].

The principle of worst action, which is increasingly used in the valve industry for gaseous fluids, will first be briefly described in chapter 2. Surprisingly, this part of physics has remained unexplored. This principle of worst action is head-on opposed to the principle of least action, hence its name.

The principle of least action stipulates that Nature does not like to get tired. Nature is thrifty in all its actions. This principle of least action covers all the fields of physics that do not take energy dissipation into account: for example, rational mechanics, analytical mechanics, etc. and even quantum physics. These domains ignore the entropy of the second law of thermodynamics and only intervene marginally when it comes to rapidly dissipating enormous quantities of energy.

Can the principle of worst action, which has made spectacular improvements in conventional valves, also be activated to weaken this special kind of valve: a hurricane? A first draft of solution will be covered in the following chapters 5-6-7.

Temperature variations of the ocean surface, under the effect of solar radiation, generate mainly thermal transfers whose origin is to be found in the molecular system. The transfer phenomena are therefore initially of a statistical nature. Fourier's law of thermal conduction is a linear approximation that is valid only when the temperature varies slowly with the distance.

During major temperature imbalances in the atmosphere, discussed in chapter 3, the phenomenon of conduction soon becomes obsolete and is quickly replaced by much more dynamic and complex convection phenomena, accompanied by mass transfers, that are still insufficiently elucidated. The equations are no longer linear and therefore

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[1] Work carried out by the author at the LTG (Laboratoire de la Turbine à Gaz - ATTAG) of CETIM (Centre Technique des Industries Mécaniques) under the impetus of Maurice Roy and Robert Legendre, Members of the Académie des sciences and directors of ONERA (The French Aerospace Lab, Office National d'Études et de Recherches Aéronautiques) and at the request of French steam-powered turbine manufacturers with the support of EDF (Électricité de France).

contain the seeds of chaos [6][7][8][9][10].

A macroscopic movement therefore appears: nature is set in motion.

- The temperature imbalance between the equator and the poles generates in particular Hadley cells.
- The temperature imbalance between the water surface and the tropopause entails complex movements leading a small event on the ocean to become a tropical depression, then a tropical storm and finally a hurricane when this imbalance in summer becomes too great.

There is another temperature imbalance, that between the ocean surface and the depths underwater. The physical conditions generally do not allow vertical convection movements to occur in tropical seas.

The Ocean is a very important energy source. Ocean Thermal Energy Conversion (OTEC) is an engine cycle utilizing the temperature difference in the tropical sea. OTEC will be subject of chapter 4.

Imagined by Jules Verne [2], described by Jacques Arsène d'Arsonval and developed by Georges Claude, the recovery of the thermal energy of the seas is a known but difficult technique to implement.

Georges Claude, in the 1930s, tenaciously demonstrated that motive power could be extracted from the temperature difference between the surface and in the water at depth. He built his first machine in a Cuban bay [11].

In Chapter 5, the construction of an underwater megastructure will be proposed. It is intended to extract cold water at depths greater than 200 meters to cool a hurricane in its lower part on the one hand and to accompany its progression on the ocean on the other.

The procedures for disorganizing a hurricane in order to weaken it are discussed in chapter 6. A hurricane needs calm and regular conditions to form. The proposed method consists in destabilizing it by reporting a lack of homogeneity in the state of the ocean. Cooling would be carried out on a specific zone in order to atrophy it and at the same time to deviate it.

We are not unaware of the difficulties of all sorts associated with this proposal, which requires a major technological leap. A first criticism made by the author is the topic of chapter 7.

However, while the task may appear Pharaonic today, this proposal, which uses the principle of worst action to destroy order in a hurricane, had to be presented, if only to stimulate thought and discussion about this untamed steam power plant over the ocean.

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[2] Vingt mille lieues sous les mers - Twenty Thousand Leagues Under the Sea (1870)

2. The PRINCIPLE of WORST ACTION

The second law of thermodynamics, which is the only physical law that takes irreversibilities into account, enabled Clausius to define entropy, i.e. in short, disorder.

To better understand what entropy was, Ludwig Boltzmann looked for its roots in the molecular world but, faced with their gigantic number, he had to use probabilities. Boltzmann then showed that entropy was related to the disorder that reigned in the molecular world.

Irreversibilities of all kinds, in an isolated system, generate entropy. In this case, the disorder thus necessarily increases with time.

In the 1970s, chaos specialists challenged the determinism of the laws of physics and showed that order was camouflaged in chaos, which was then called deterministic chaos. When a system is carried far away from its initial equilibrium, it passes through bifurcation points and crosses chaotic zones, before structures composed of order and disorder emerge: these are Ilya Prigogine's dissipative structures [12][13][14].

Dissipative systems increase disorder but can also create order. The only condition consistent with the second principle of thermodynamics is that as a whole, disorder increases.

Dissipative structures

The most imposing example of dissipative structures, but perhaps the simplest to describe even though it is inaccessible to us and will probably remain mysterious, is that of our Universe. Why is it necessary to wait billions of years after the initial fantastic temperature disequilibrium due to the Big-Bang to reach the final equilibrium where everything will be homogenized? Because dissipative structures appeared to hinder this march towards ultimate disorder. Order emerged. These dissipative structures, or self-organized structures, are planets, trees, birds, . . . life. Order was born from disorder while bringing hope to mankind.

However, the dissipative structures thus formed are sometimes unacceptable. The reason is that the order which is introduced in such a system, after crossing chaotic zones, prevents it from quickly reaching its final point of equilibrium. While this is fortunate for our Universe, it is unwelcome in other situations. The cases are certainly very few in number, but they are crucial because they are very dangerous for our safety.

Examples include the orderly supersonic jets in the control valves which make our large power plants vibrate and risk weakening them, or the self-organized hurricanes resulting from an excessive imbalance in nature, which die out after having created havoc on land.

By using its collective intelligence, the molecular system organizes itself to degrade the kinetic energy of the flows in valves by itself, at its own pace, without worrying about our safety or our installations [4][5][15].

Is it sensible nowadays to let chaos invade safety valves (and other

expansion devices) when they are responsible for protecting people, facilities, and the environment?

Is it wise to allow the microscopic world, at certain partial loads, to seize the control and regulation devices of our major energy installations?

It is imperative that the order that appears in dissipative structures that have become threatening be destroyed.

The principle of worst action, by exchanging information from our macroscopic world to the molecular world, proposes to reverse the roles: namely, to impose great disorder in the molecular system so as to disintegrate the order contained in these harmful dissipative structures and thus to protect our macroscopic world.

The principle of worst action, by destroying Prigogine's dissipative structures, shortens time. It enables Boltzmann's point of final equilibrium to be rapidly attained by also avoiding the chaotic phenomena that precede dissipative structures.

It is its "*armed wing*", the entropic vistemboir (or simply a vistemboir), which is different obviously in each case, that is in charge of applying this principle of worst action.

Rehabilitation of the second law of thermodynamics

The laws of thermodynamics formulated by Sadi Carnot and Rudolf Clausius when grouped together can be written:

***Energy is conserved but energy is degraded*.**

The principle of worst action extends the second principle of thermodynamics to the case of dissipative structures to be eliminated (valves, hurricanes, etc.). The laws of thermodynamics then become:

Energy is conserved but energy must sometimes be degraded.

This principle of worst action shows our determination to prevent the microscopic system from taking over large-scale energy systems that are considered dangerous for mankind. By freeing the second principle of thermodynamics from the constraints due to the chaotic phenomena that limit it, it gives it its full potential. Entropy can then increase much more quickly.

By shortening the lifetime of structures that are dangerous for our safety, the principle of worst action allows the unpopular second principle of thermodynamics to regain credibility.

3. DISEQUILIBRIUM in the OCEAN-ATMOSPHERE SYSTEM

The temperature imbalances observed everywhere in nature are subject to the laws of thermodynamics and transport phenomena.

Carnot's principle states:

"***Wherever there is a difference in temperature, motive power can be produced.*** "

Thermal conduction is the transfer of kinetic energy during molecular collisions. The hot molecules which are faster communicate energy to the cold molecules which are slower. The phenomenon of transport by conduction thus acts by gradually transferring heat energy via the molecules that are grouped in particles in the continuous media of our macroscopic scale. Thermal conduction thus occurs naturally from hot to cold zones, in accordance with Clausius' postulate, another presentation of the second law of thermodynamics, which stipulates that:

"***Heat cannot, of itself, pass from a colder to a hotter body.***"

3.1. Temperature disequilibrium between the equator and the poles

The temperature difference between the equator and the poles, due to solar radiation, creates a disequilibrium which leads to a general convection movement in the atmospheric layer, and to a lesser extent in the ocean.

Masses of fluid are set in motion between the equator and the poles.

These displacements do not take place along meridian lines since the Coriolis effect due to the rotation of the Earth deviates them. This fictitious force exerts a strong influence on the moving masses and forces them to split the transfer by convection from the equatorial hot spring to the polar cold source into three successive stages.

The only stage that concerns the phenomena covered by this article relates to the cells known as Hadley cells which develop between latitude 0 (equator) and latitudes 30, the zone in which hurricanes occur. These cells form discontinuous toric cylinders encircling the terrestrial globe.

3.2. Disequilibrium between the surface temperature of tropical seas and that at high altitude - tropical depressions, tropical storms, hurricanes

This disequilibrium allows the emergence of random tropical low pressure zones over the ocean. These initial lows are likely to become firstly tropical storms then perhaps hurricanes depending on the weather conditions encountered by these phenomena during their displacements. This is the signature of chaos, i.e. a sensitivity to initial conditions. Almost identical initial conditions may or may not lead to phenomena of completely different magnitudes [6][12].

Hurricanes can occur in the same zone as Hadley cells with which they interfere in a complex manner.

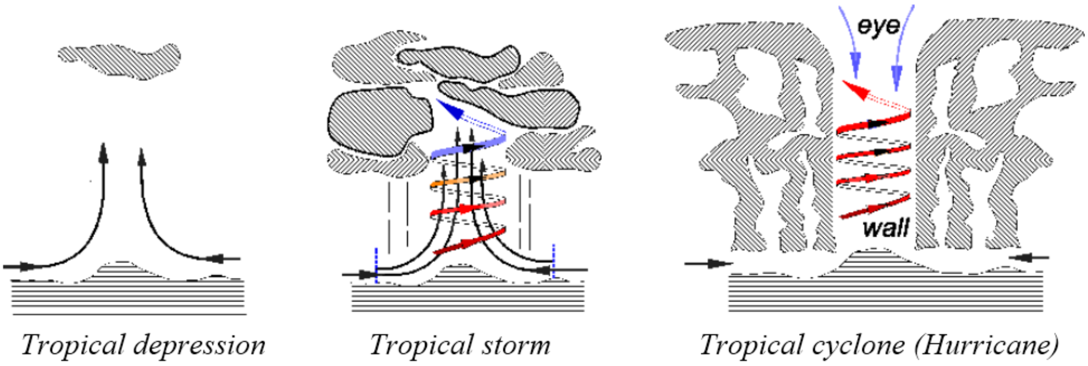

Figure 2: Hurricanes: a demonstration of chaos

3.2.1 Chaotic hurricanes [16]

During the summer months, tropical storms, in which disorder reigns, are unbalanced by the great temperature difference between the ocean surface and the limit of the troposphere, and are radically transformed into a very ordered hurricane after passing through a bifurcation and a more or less chaotic zone. A hurricane is a dissipative structure that exchanges matter and energy with the waters of tropical seas. It is composed of order and disorder. The self-organization of a hurricane is manifested by its almost perfectly circular eye bordered by the eyewall.

The dissipative structure of a hurricane operates like an open-air thermal engine. The hurricane draws its fuel from the reservoir of heat formed by the top layers of the ocean: this is the cycle's hot source. The hurricane releases a quantity of heat to the cold source at high altitudes.

The motive power resulting from the hurricane's thermodynamic cycle is used by the hurricane to pump more fuel from its hot source and thus swell alarmingly.

It should be noted that a tropical storm does not have the capacity to create driving energy. It is the order created during the formation of the hurricane that generates the thermal engine.

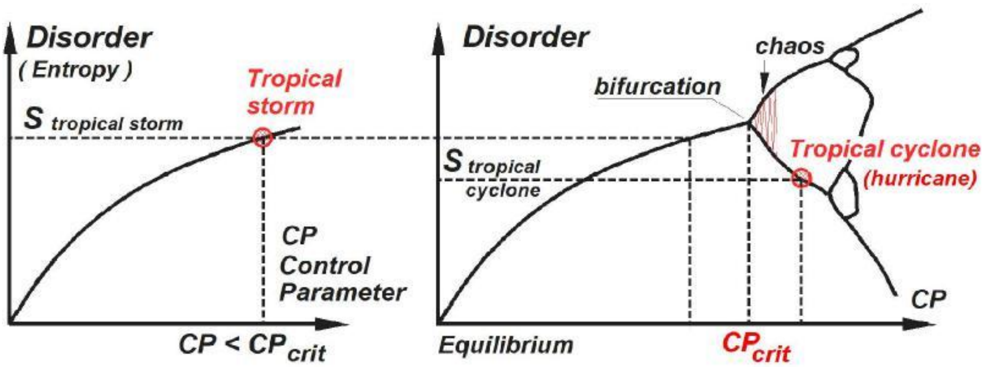

Figure 3: Bifurcation diagram of a hurricane, according to [16]

The entropy of this weather system decreases when a tropical storm turns into a hurricane (Figure 3). According to Shannon's information theory, entropy measures the loss of information by a system. Conversely, a system having received some information is ordered, its entropy decreases. When the weather system is organized in a hurricane, it has received information on the state of the sea, transmitted by the collective intelligence of the molecular system. Convection phenomena lead to a monumental spatial organization regulated by correlations between molecules.

3.2.2 Conditions for the occurrence of a hurricane

A hurricane is formed when the following conditions are met: [1][2][16]

- the temperature of the ocean exceeds 26^{o}C, over a few tens of meters of depth, forming a significant heat reserve which, on vaporizing, will allow the hurricane to form and persist,
- strong evaporation, accompanied by abundant clouds in the Earth's atmosphere up to the limit of the troposphere (approximately 15 km), resulting in a tropical depression,
- homogeneous winds from the ocean surface up to the limit of the troposphere,
- a latitude greater than 5 degrees so that the Coriolis effect can come into play. This effect due to the rotation of the Earth does not create wind; it only deflects an existing wind, diverting it eastward into the northern hemisphere.

It is therefore in tropical zones, around 5 to 8 degrees of latitude, where the above conditions are met, that hurricanes are likely to form. The hurricane system thus generated will be able to maintain itself as long as its supply of hot water for vaporization is sufficient.

Cut off from its hot water supply, a hurricane weakens. Then it starts to die out as soon as it touches land and disappears completely after having travelled a sufficient distance over land and causing its share of havoc.

3.3 Disequilibrium between the surface and depth temperatures

The electromagnetic waves emitted by the sun are captured by the surface water layer of the oceans where they are converted into thermal energy. In summer, the strong radiation of the Sun increases the surface temperature of tropical seas, which can reach 26-27^{0} C.

The density of water in tropical seas follows the evolution of the temperature. The warmer the water, the lower its density.

In tropical seas, the lowest density is located in the water layer close to the surface where it is almost constant, then starting from the thermocline (transition zone between the hot and cold masses), it increases very quickly with depth. The warm water masses near the surface then act like a lid on the colder, higher-density water masses that remain in the depths of the ocean. The temperature distribution in tropical seas by depth is shown in figure 4.

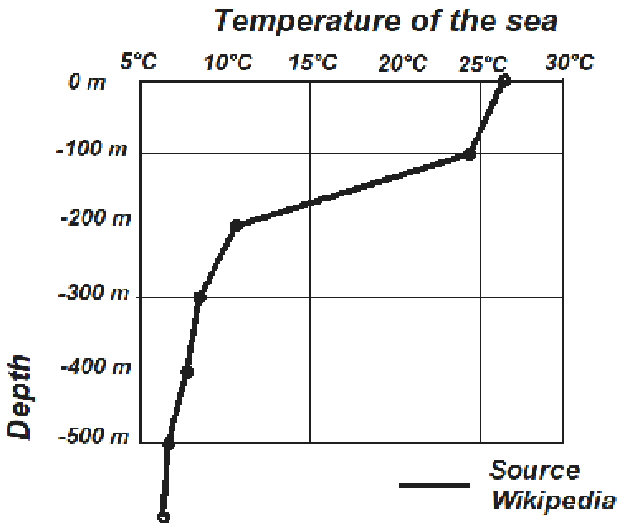

Figure 4: Variation of temperature in tropical seas by depth

Under the thermocline, the strong variations in density prevent convective motion. Any water particle that is moved vertically upwards, by an unspecified process, will quickly sink back down to its initial position, in accordance with Archimedes' hydrostatics. The situation in the ocean depths seems a priori relatively stable. In the near-surface zone, where the density evolves slowly, vertical convection movements can sometimes be observed in the presence of strong turbulence.

4. The THERMAL ENERGY of the SEAS

Installations to recover thermal energy from the seas (Ocean Thermal Energy Conversion - OTEC)[3] function with two sources, in accordance with the principle of Carnot, one hot source corresponding to the surface temperature, and a cold source corresponding to the ocean depths.

A utopia that has become reality[11]. Convinced of the enormous potential of the thermal energy of the seas, and the creator in 1926 of an OTEC cycle, George Claude made a firm commitment to demonstrate the merit of this idea. These OTEC machines, currently under development, are installed close to the coasts in order to supply the island populations with electric energy.

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[3] OTEC (Ocean Thermal Energy Conversion) denotes both the energy resource and the processes of exploitation. The French acronym is ETM (*Énergie Thermique des Mers).*

OTEC Thermodynamic Cycle

The efficiency of a Carnot cycle is independent of the heat transfer fluid used. In practice, however, the nature of the fluid plays an important role because its physical properties may be more or less well suited to the realization of the evolutions. In OTEC facilities, water or ammonia is used. Ammonia is of great interest for the sizing of facilities because an ammonia steam turbine will be much smaller than a water steam turbine.

An example of a thermodynamic cycle capable of producing mechanical work is shown in figure 5. Warm water from the ocean surface provides a quantity of heat Q_b to the liquid in the steam generator (or evaporator). The transfer of heat Q_a to the cold source is done by converting the vapor to the liquid state in the condenser from where the calories are evacuated to the outside via a pump.

The adiabatic transformations take place in the expansion turbine and in the feed pump that increases the pressure prevailing at the condenser to that at the evaporator. The mechanical energy can be collected by an alternator or a pump.

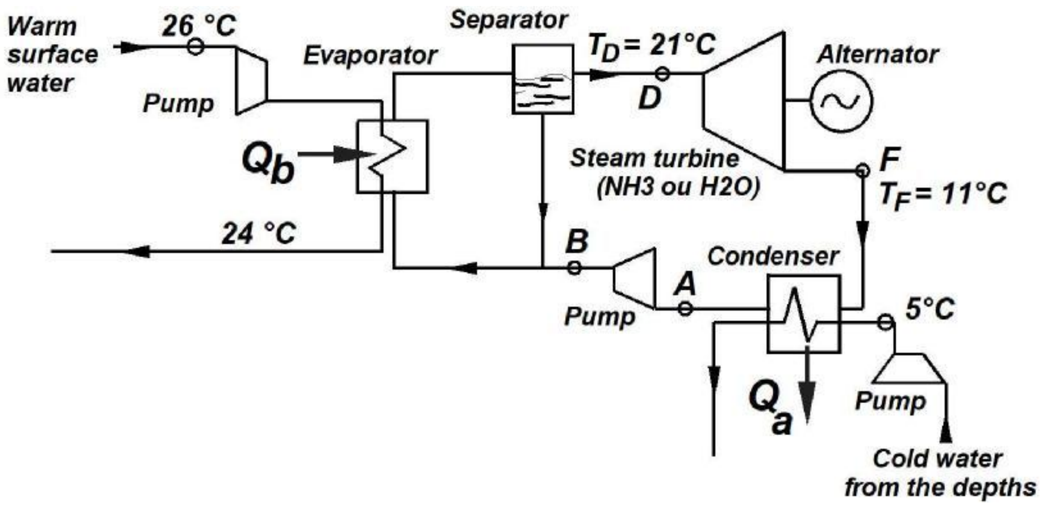


Figure 5: OTEC geothermal cycle functioning between the temperature of 26°C and 5 °C

5. SKETCH of a VISTEMBOIR to WEAKEN HURRICANES[4]

Can the principle of worst action, which has proved effective in escaping chaos and harmful order in the control and safety devices of power plants, also be applied to lessen tropical cyclones?

The vistemboir is a means of applying the principle of worst action; it aims to destroy the order built by chaotic phenomena.

It is obviously easier to build a vistemboir in the confined space of a valve [4][5][15]

[4] International patent applications filed

than in the case of an open-air hurricane.

The main aim is to remove the hurricane from the chaotic zone in which it is trapped and downgrade it to a tropical storm by destroying the order introduced after a bifurcation.

This objective should be achieved by locally and continuously cooling the ocean surface water at specific places at the base of the eyewall of a hurricane by pumping cold water from the depths, in order to destabilize the hurricane and thus weaken it until it is downgraded to a tropical storm that is less aggressive, much more acceptable and useful in the organization of the Earth's atmosphere. During this progressive degradation, a secondary objective consists in gradually driving this hurricane, by the Coriolis effect, towards the cooler oceanic basins in order to weaken it even more.

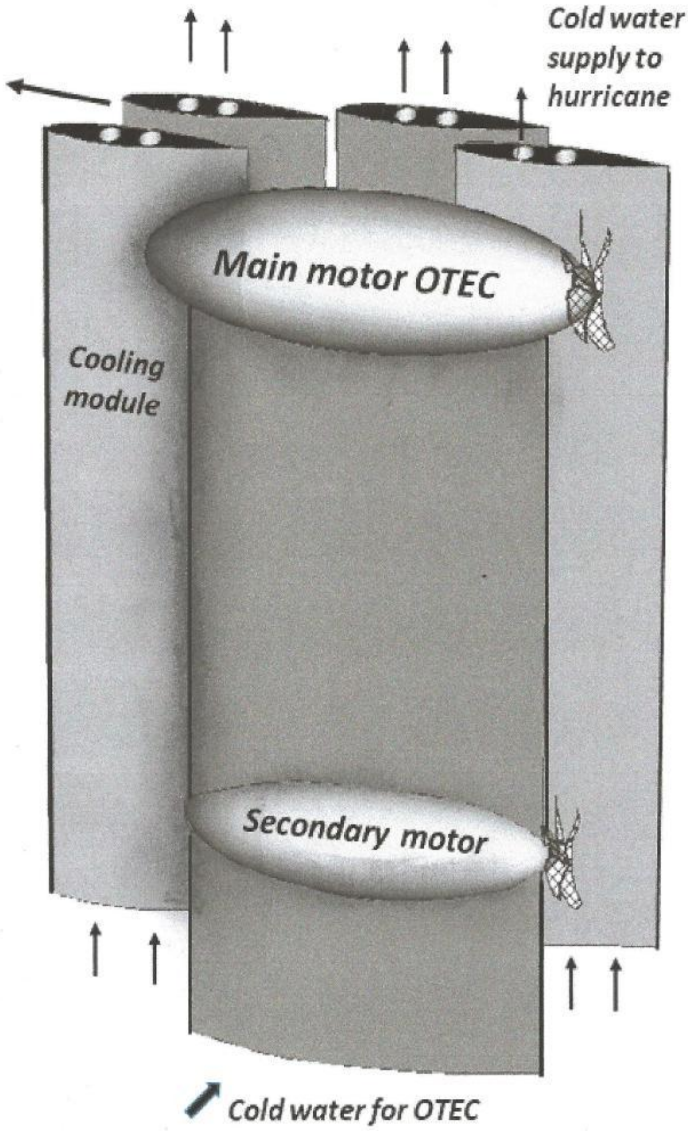


Figure 6: A vistemboir applied to hurricanes (Exploded view)

As long as the system is a tropical storm, the energy dissipates by itself. The principle of worst action does not need to be applied a priori. However, as soon as the system becomes a hurricane and the degradation of energy is disrupted because it is no longer complete, then the principle of worst action must be activated in order to destroy the ordered part introduced during the self-formation of this hurricane. This action of eliminating order in a hurricane must be pursued and brought to its completion, i.e. the extinction of this mad thermal power plant on the surface of tropical seas.

The only accessible parameter is a priori the temperature of the warm water reservoir, which feeds the hurricane. If the base of a hurricane can be sufficiently cooled, one can hope to disturb it and weaken it.

To achieve this goal, it is not necessary to fetch cold water from the poles because it can be found a few hundred meters below the surface of tropical seas. Just go get it! But pumping up the cool water that is maintained by physics in the depths of tropical oceans is no easy task.

By preventing cold water from the depths of tropical seas from rising to the surface, physics offers us a remarkable natural storage of energy. It is from this reservoir that we will draw, sparingly, the necessary energy to try to extinguish a hurricane.

For that purpose, it is proposed to separate OTECs from coastal areas and turn them into seagoing vessels. The energy produced by the OTEC thermodynamic cycle will be used on the one hand, for pumping the deep water needed to cool the hurricane wall, on the other for the propulsion of a submarine to intercept and track the hurricane.

The vistemboirs will be placed under the hurricane and will follow it along its journey in the ocean; they will be to some extent coupled with the hurricanes.

The two thermal machines, "*hurricane*" and "*vistemboir*", obey the laws of thermodynamics. Both draw their energy from the warm surface water of tropical seas in the same place. Their cold source is the upper atmosphere for the hurricane and a depth of a few hundred meters below the ocean surface for the vistemboir.

The treatment of a hurricane thus becomes a local problem which must be treated locally, without any outside intervention, a priori.

A mature hurricane possesses a considerable motive power. A fleet of vistemboirs is necessary to try to disrupt a fully-formed hurricane. We must act quickly as soon as the hurricane self-organizes - or even before - to counter it. Meteorologists are nowadays capable of predicting with sufficient accuracy where and when a tropical storm risks rapidly becoming a hurricane.

Megastructures to break down a hurricane

The exploitation of renewable energies generally leads to large, expensive, and inefficient installations. The OTEC does not derogate from this rule. In spite of these inconveniences, Jules Verne's initial idea of using temperature differences in the seas remains very exciting [11].

The process involves unmanned vessels (without fuel and without operators a priori) remote-controlled from a base, and designed to destabilize hurricanes.

These megastructures ("*Hurricane Vistemboirs*") motorized and armed for navigation in rough seas, do not require any external input to operate.

These ships sail towards the tropical storms likely to become hurricanes and on approaching the highly turbulent zones, they sink into the sea deep enough below the surface to escape the disturbances as much as possible. They are piloted so as to be positioned in specified locations beneath the hurricane and then navigate in a stationary position relative to it.

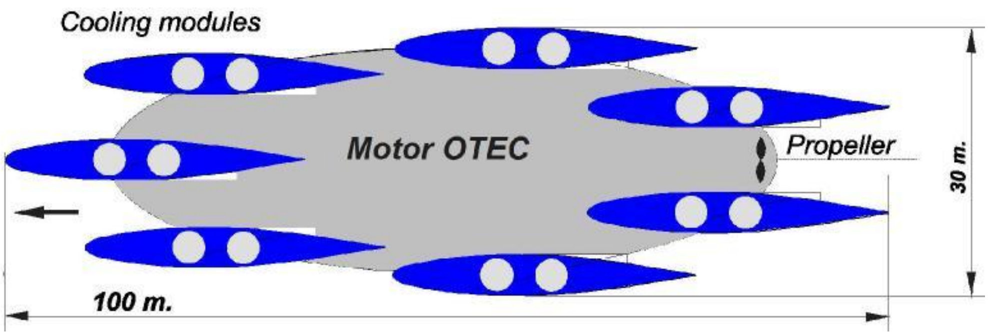


Figure 7: Hurricane Vistemboirs - top view

What a hurricane vistemboir might look like.

The two requirements recalled below necessarily lead to a marine superstructure, such as that presented in figures 6 and 7.[5]

- pump the cold water from about 300 meters deep up to the surface.
- be able to track a hurricane with an average speed of displacement of 25 km/h.

This structure comprises mainly: (Figure 6)

- The main motor, based on an OTEC, which is housed in an ovoid body 25 meters in diameter. The mechanical energy produced by this central body is mainly used for the propulsion of the underwater vessel and the pumping of the cold water at a depth of 300 meters where the water temperature is about 10 ^{o} C.
- The secondary motor, which is subjected to a pressure greater than 10 bar, is similar to an anaerobic AIP submarine (Air Independent Propulsion). This motor has a diameter of about 10 m and receives its power from the main engine to drive its own propellers and accessories.

[5] The author does not claim, with this thought experiment, to oust naval architects, who are competent to either decide that it does not come within their field of expertise, or to modify it to make it compatible with the rules of their art.

- The cooling modules are assembled on the main motor body and also on the secondary body in such a way that the unit forms a system that is hydrodynamically stable by avoiding the harmful hydraulic interferences between them (Figure 7). These modules are thermally insulated.

All external parts are of course subjected to the laws of hydraulics. In order to reach the speed of displacement of the hurricane, the main body and its cold water supply pipe, the secondary body, and the cooling modules are designed with a suitable profile (Figure 8).

The cooling modules, in particular, are profiled according to best practices in order to limit hydrodynamic drag (profile NACA 65012 for example, well-known to aerodynamics engineers, and similar to the aerodynamic shapes of fish).

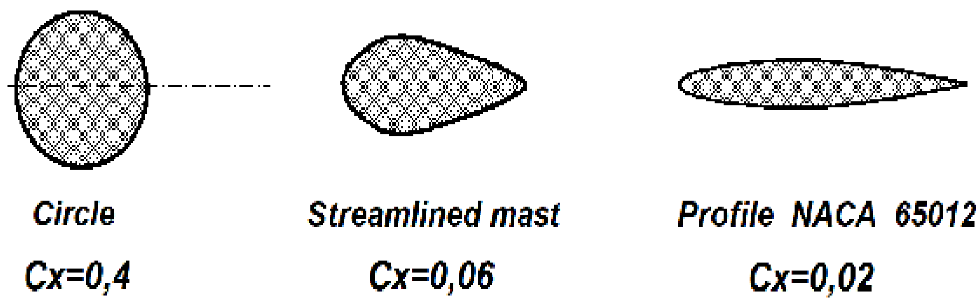


Figure 8: Drag coefficient Cx of various profiles

- The insulated cooling modules are equipped with water intake devices in the lower part. While the speed of the water in the ducts is about 2 m/s, a convergent nozzle in the upper part allows the cooling water to reach the speed of the submarine (about 7 m/s) so that the ejection into the ocean is as undisturbed as possible.

Example of global characteristics of a hurricane vistemboir

For a hurricane displacement speed of 25 km/h, a pre-dimensioning gives:

- Pumping and drive power: 56 MW
- Pumping power: 16 MW
- Power required to overcome hydrodynamic drag: 40 MW
- Water flow for cooling the hurricane: 420 m^3/s
- water intake at a depth of 300 m. for the cooling modules,
- water intake at a depth of 400 m. for the cold water supply of the OTEC thermodynamic cycle.

6. METHOD to WEAKEN a HURRICANE

Let us assume that the submarine “*hurricane vistemboir*” is at last built, after many difficulties.

A certain number of submarine ships form Armada 1 and another group forms Armada 2. They are used to cool two distinct zones of the hurricane and not the whole surface, which would be both unreasonable and unproductive.

Breaking up a hurricane means that its organization must be disrupted, which can be achieved by altering it with a massive injection of cool water in precise places. Molecular movements coordinated by long range correlations are thus deteriorated and the hurricane’s self-organization is destroyed little by little.

Procedure to weaken a hurricane (example in the North Atlantic)

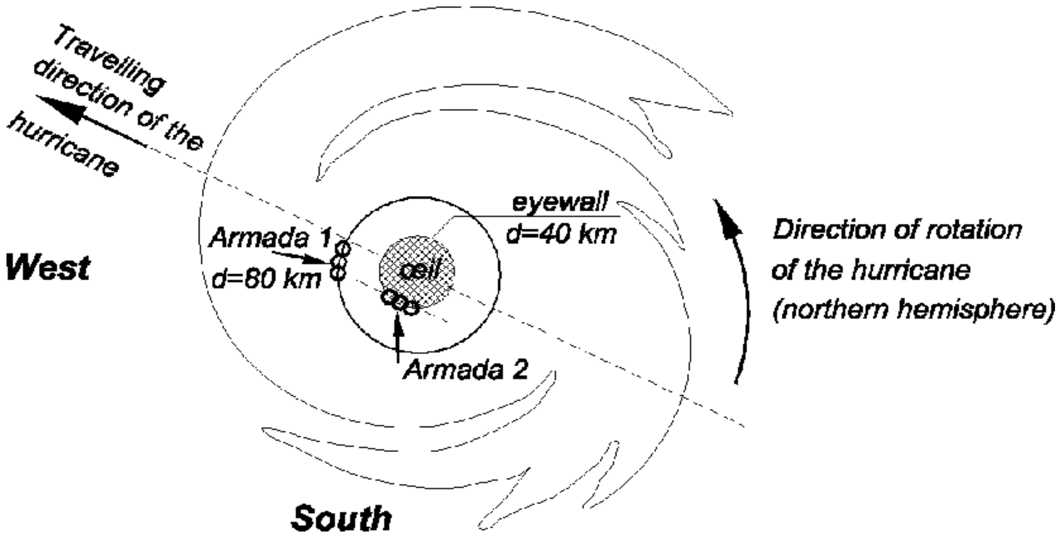
Phase 1: Installation of the Armadas of vistemboirs in the suspected zone, and monitoring of the depressions and tropical storms, thanks to information from specialized weather centers, so as to intercept them as soon as possible after their transformation into hurricanes, i.e. as soon as the eye appears. This corresponds approximately to the moment when the hurricane is classified as a category 1 hurricane on the Saffir-Simpson scale.'

Phase 2: Positioning of the Armadas of vistemboirs under the eyewall by placing them as close as possible to the surface yet at a depth such that surface disturbances are sufficiently attenuated and admissible.

- Position Armada 1 under the eyewall in the area marked on figure 9 (under the hurricane’s displacement axis, about twenty kilometers upstream of the eyewall) and begin cooling.
- Position Armada 2 under the eyewall along the tangent to the parallel to the hurricane’s displacement axis (see figure 9) and begin the cooling operation.

Phase 3: Displacement of the device. The complete set of ships (Armadas 1 and 2) piloted from an observation station, will be displaced at the speed of the hurricane by maintaining its position relative to the eye.

All these actions impede the self-formation of a hurricane and therefore alter its behaviour.



Expected effects

- Progressive destabilization of the hurricane. The massive, continuous injection of cold water under the eyewall may lead to:
  - gradually deconstructing the hurricane system by weakening the correlations between the billions of billions of molecules forming this immense self-organized structure, i.e. by introducing disorder into the ordered part of the hurricane.
  - weakening the system by introducing a certain shear into the winds spiralling around the eyewall. A heterogeneous wind profile unbalances the hurricane, which needs regularity in all areas in order first to form and then to develop

Modifying the hurricane's trajectory. The injection of colder water at the above-mentioned places should block the hurricane's path towards the warmer water.

This massive intake of cool water is a trick designed to take control of the hurricane. The natural tendency of the self-organized hurricane system, like that of all dissipative structures, is to increase its power by exchanges with the environment. The molecules close to the ocean surface will transmit to the complete molecular system called a hurricane the information that in the W-SW direction the water is cold and that it is therefore preferable for the whole system to choose the NW-N direction where it will be able, from its point of view, to feed and grow in better conditions.

- Accentuating the Northwesterly direction by the Coriolis effect. The Coriolis effect is null at the equator and it grows as one moves towards the poles. From 5 degrees of latitude, it begins to be weakly active. The hurricane will therefore be subjected to the Coriolis initial force all the more as it has been displaced towards the northern latitudes where it will be driven little by little towards its right.

7. CRITICISMS and REFUTATIONS

On the road to building a hurricane vistemboir, there are many obstacles and overcoming them will require a significant technological leap. However, they don't seem to be prohibitive in the longer term. Here is a non-exhaustive list:

- The motive powers of machines using thermal energy from the sea are currently about 20 MW. The increasing skills of various industrial players developing this sector make it possible to consider powers of 100 MW by 2030.
- These machines should benefit from the rapidly growing underwater operations market. Companies in the oil sector specialize in the implementation of underwater infrastructures with a high technological added value.
- The ships would be equipped with a remote control system; this technology is only at the evaluation stage for the moment.
- These numerous megastructures of non-standard dimensions - which could be related to offshore oil installations - are also mobile: their performance at sea thus remains to be proven.
- The working fluid used for the thermodynamic cycle can be water or ammonia. Although water is the ideal solution, the use of ammonia is much more realistic for the sizing of the installation, which is unfortunate because there are certain drawbacks and obligations with respect to the environment with ammonia. An alternative solution consists in opting for the anaerobic propulsion systems of submarines (AIP), which can operate for several days underwater without using outside air. They are therefore well adapted because hurricanes also die out after about a week of existence. Several techniques are used, ranging from the use of liquid oxygen for Diesel-electric submarines to technologies such as fuel cells.

The construction, installation and sea-worthiness of the piping system are highly complex operations when manufacturing machines which take advantage of the thermal energy of the seas. The pipes of the project presented above are shorter but mobile, which adds to the difficulties. Furthermore, shorter pipes lead to higher temperatures of the cold source of the thermodynamic cycle, making it more difficult to carry out. On the other hand, mobile exchangers will be more efficient than exchangers in fixed positions close to the coast.

The constraints are thus very strong and affect the solution suggested but without discrediting it. It deserved to be presented nevertheless, if only to submit it to constructive criticism. Other more relevant solutions may (hopefully) emerge.

8. CONCLUSION

As the solution proposed here involves cooling a portion of a hurricane, it is necessary to use pumps that bring cold water from the depths to the surface. Physics teaches us that we must expend mechanical energy to carry out this operation, which is not spontaneous.

Naturally, it was necessary to consider large structures with a height of more than 200 meters − to reach the cold waters − and to use a pumping system with a high flow rate in relation to the portion of the hurricane being cooled.

The decision to follow the hurricane in its displacement is very expensive in terms of energy and greatly complicates the task because the entire device must be streamlined to facilitate its penetration into the water.

While at first sight the dimensions of vistemboirs may seem shocking, they become much less so when compared to those of hurricanes. A vistemboir is just the "*gadfly*" of a hurricane. The construction cost should be compared with the cost of the damage caused each year by hurricanes.

This text has pointed out the beneficial role of the principle of worst action associated with the unavoidable second law of thermodynamics.

The fleets of vistemboirs appear capable, through cumulative effects, of weakening a hurricane and leading it gradually towards uninhabited maritime zones, downgrading it little by little to a tropical storm that is much less aggressive and extinguishes faster.

By gradually degrading this dissipative structure in the open sea, it is prevented from reaching and creating havoc in the inhabited lands of the Caribbean and North America. The process presented here was based on hurricanes in the northern hemisphere; it also applies obviously to the other ocean basins, the typhoons of the Pacific Ocean and the cyclones of the Indian Ocean, but in these cases it is necessary to take into account the inversion of the Coriolis effect when the equator is crossed.

Though only a thought experiment for the moment, the hurricane vistemboir shows that it may be possible, at the cost of a significant technological leap, to calm down these formidable weather events that nature builds under our eyes.

We, the human race, have the great advantage over nature of being endowed with reason. If we do not use this reason to tame hurricanes, then we will have to suffer their misdeeds more and more. We will have thus refused, in the face of history, to understand nature and to help it by capitulating to its excesses.

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