Learning about hurricanes: Parabolas, Spirals, and Trochoides

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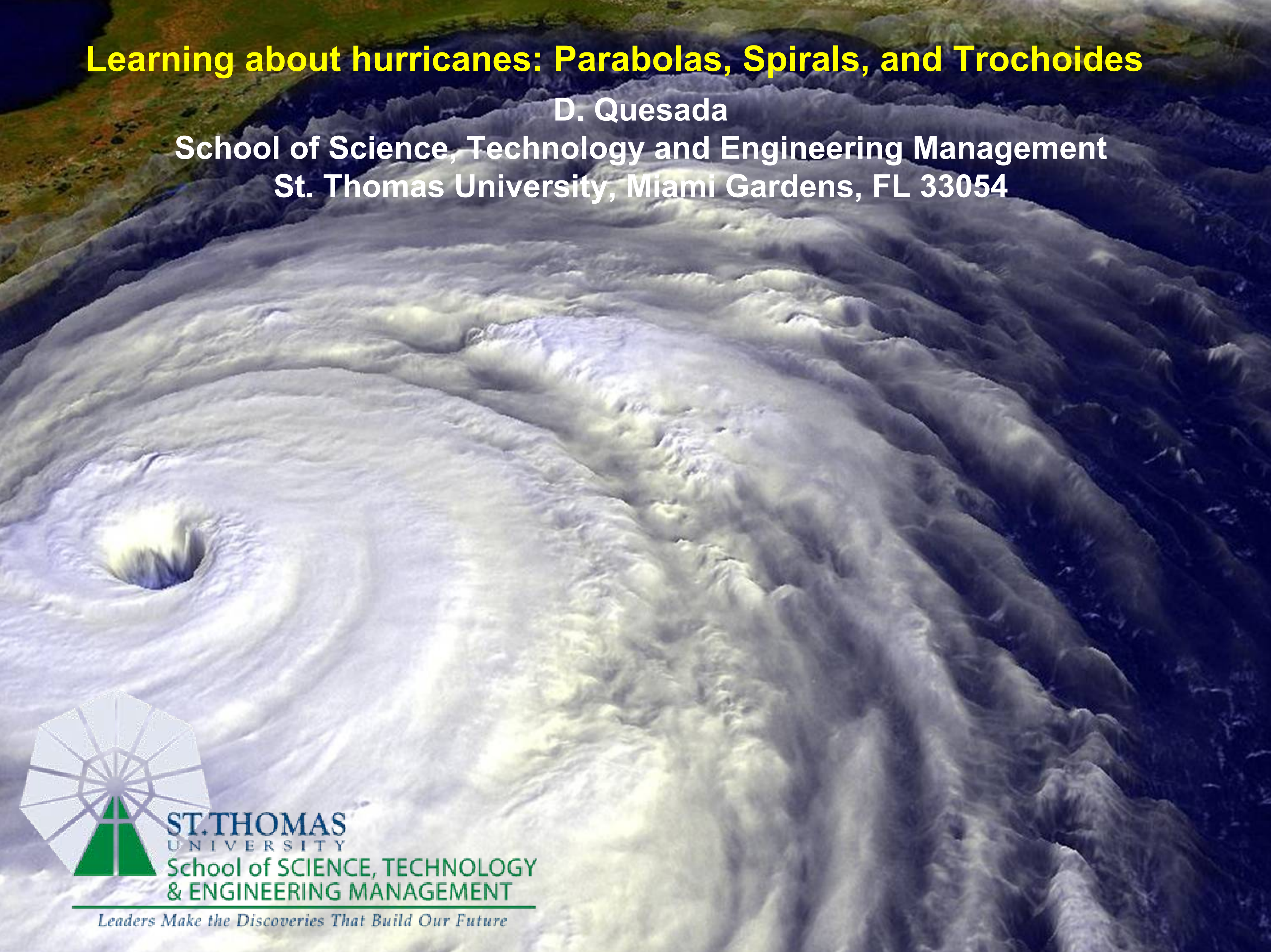

ST. THOMAS UNIVERSITY
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Leaders Make the Discoveries That Build Our Future

Welcome to Florida
Our house is here
We are here
Our car is here
Our dog is here

Special Report: Why New Orleans Still Isn't Safe
TIME
Two years after Katrina, this floodwall
is all that stands between
New Orleans and the next hurricane.
It's pathetic.
How a perfect storm of big-money politics,
shoddy engineering and
environmental ignorance is setting up the city
for another catastrophe.
BY MICHAEL GRUNWALD

Florida...
The
Sunshine
PLYWOOD State

During the time of Greeks and Romans, mythology was part of the cultural legacy left by these two cultures. The name Gaia, the goddess of planet Earth competed in beauty with Venus or Aphrodite. Many other characters were part of this celestial family of creatures.

Pre-Columbian cultures, as Mayans, Aztecs, and Caribbean Indians Tainos, developed their own body of goddess too. One of those was Juranken, the goddess of fury for Mayans, and Jurankán, the evil of winds for Tainos in the Caribbean. After the conquering of America by the Spanish royalty the word Jurankán evolved into what we know today Huracán.

The incursion of English and French pirates in the Caribbean probably introduced the word into the English colonies as Hurricane. According to Fernando Ortiz, a Cuban historian who wrote a book about the history of Hurricanes; there are archeological evidences that Caribbean Indians were aware of the spiral pattern today observed in hurricane rain bands. It is known also that the awareness of Tainos about hurricanes saved Columbus' fleet of a shipwreck during an incident in La Hispaniola, when the governor did not permit Columbus to be in a city.

Weather Laboratory

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Born in Catalan, Spain 1837
came to Havana Cuba in 1870 as Director of the Meteorological Observatory in the Royal College of Belén.

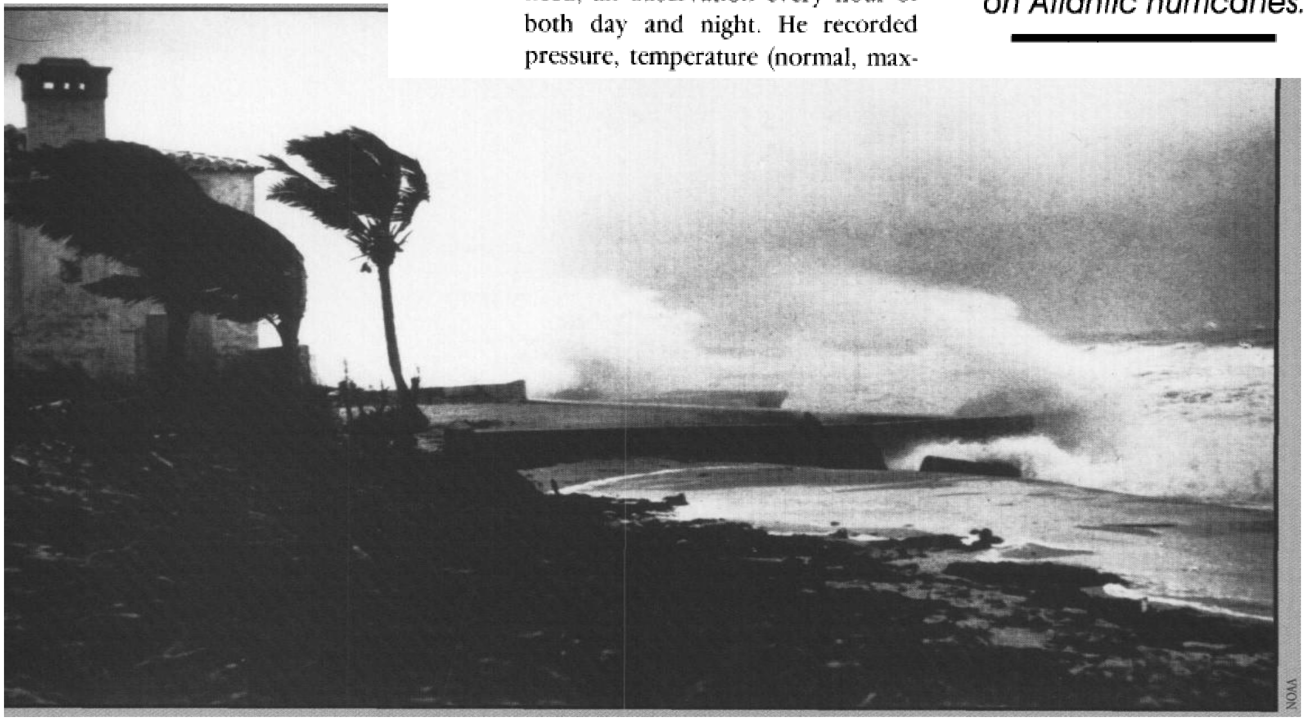
He was a Jesuit and a Scientist. Died Havana, Cuba July 23, 1893.

through debris and questioning survivors. Everything was painstakingly recorded.

Father Viñes developed a demanding daily weather observation schedule for himself. This included observations every hour from 4 a.m. to 10 p.m., an international observation at 7:30 p.m. and, in times of special need, an observation every hour of both day and night. He recorded pressure, temperature (normal, max-

In his day, the Reverend Benito Viñes was the world's greatest authority on Atlantic hurricanes.

the storm's center, and he was also the first to forecast hurricane movement on the basis of cloud movement. The *Pilot Charts* of the U.S. Hydrographic Office printed and reprinted the "laws" of Father Viñes. The May issue of the 1889 *Pilot Chart* reads: "These important laws, established by the study and long experience of Father Viñes, should be thoroughly understood by every navigator and utilized by shaping his course so as to

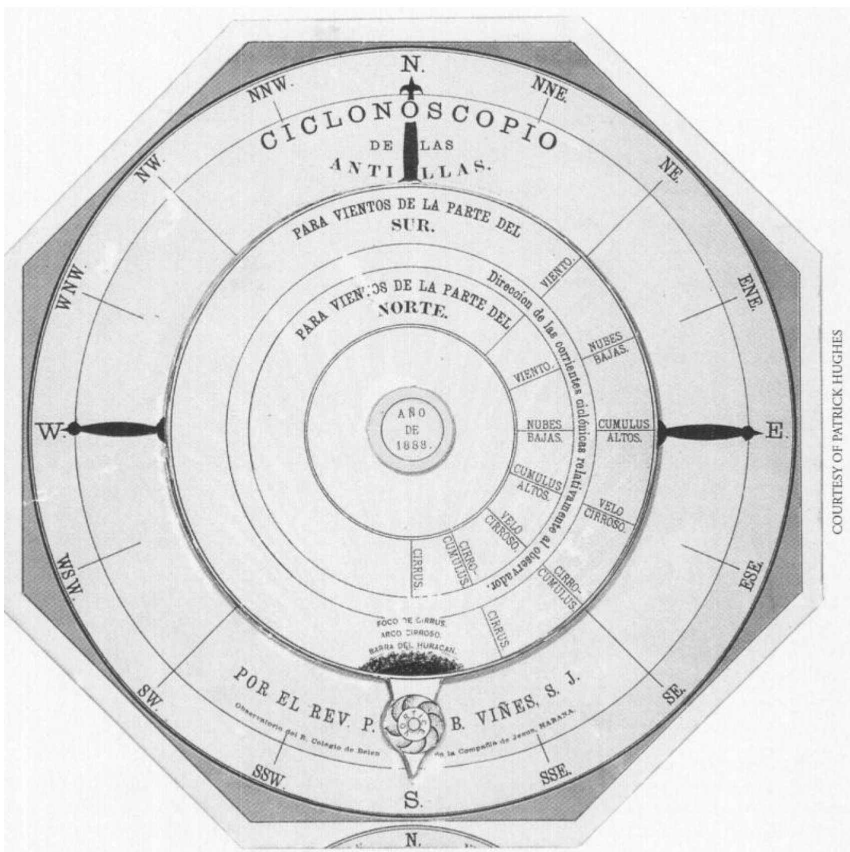

NOAA

1875, he established Viñes Law, essential to the study of tropical storms

The May issue of the 1889 Pilot Chart reads: "These important laws, established by the study and long experience of Father Viñes, should be thoroughly understood by every navigator and utilized by shaping his course so as to avoid a hurricane."

Father Viñes was the first

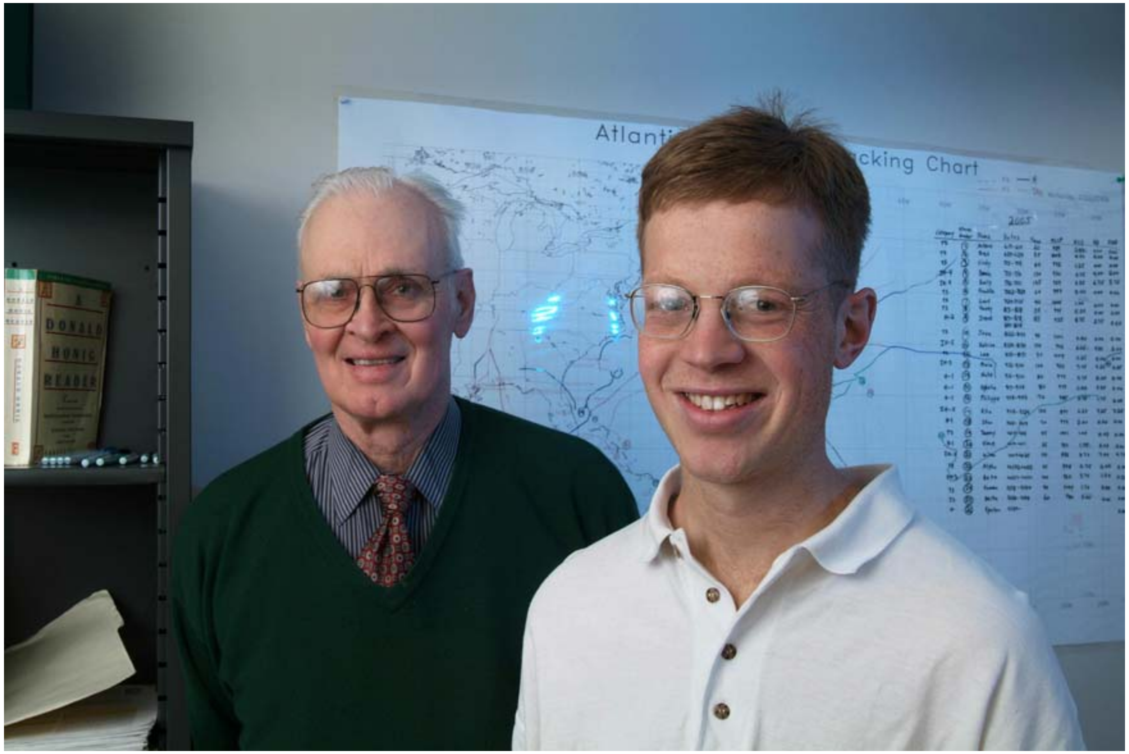
- to suggest that the clouds well in advance of a hurricane could be used to locate the storm's center
- the first to forecast hurricane movement on the basis of cloud movement
- discovered the first law of anticyclones of the Caribbean



Father Vines invented the Antilles Cyclonoscope to help other forecasters detect, locate, and track hurricanes and determine their size and intensity. The interior circle and the pointer labeled "vortice" (bottom) rotate with respect to the outer compass, showing the bearing of the eye of the storm in relation to surface wind direction and cloud movements at various levels.

On October 6, 1900, Willis L. Moore, Chief of the U.S. Weather Bureau, wrote in Colliers Weekly that ". . . probably the Reverend Benito Viñes gave more intelligent study to the investigation of tropical cyclones than any other scientist."

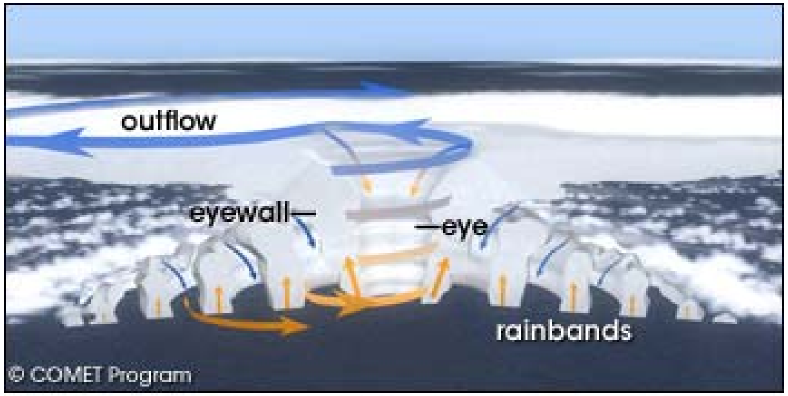
Hurricane Science – New Generations

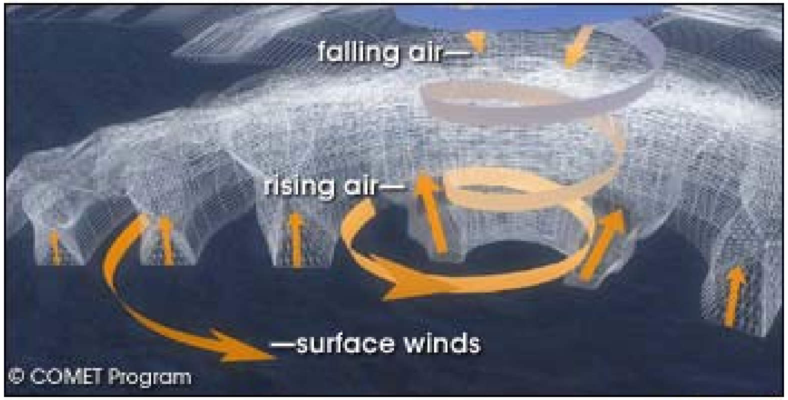


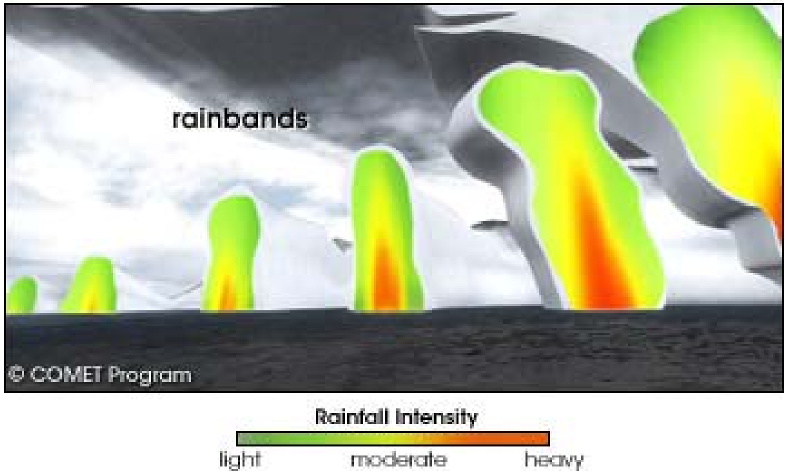
Dr. William M. Gray and Phil Klotzbach, both from Colorado State University, head the Tropical Meteorology Project at CSU's Department of Atmospheric Sciences. Dr. Gray is a pioneer in the science of forecasting hurricanes.

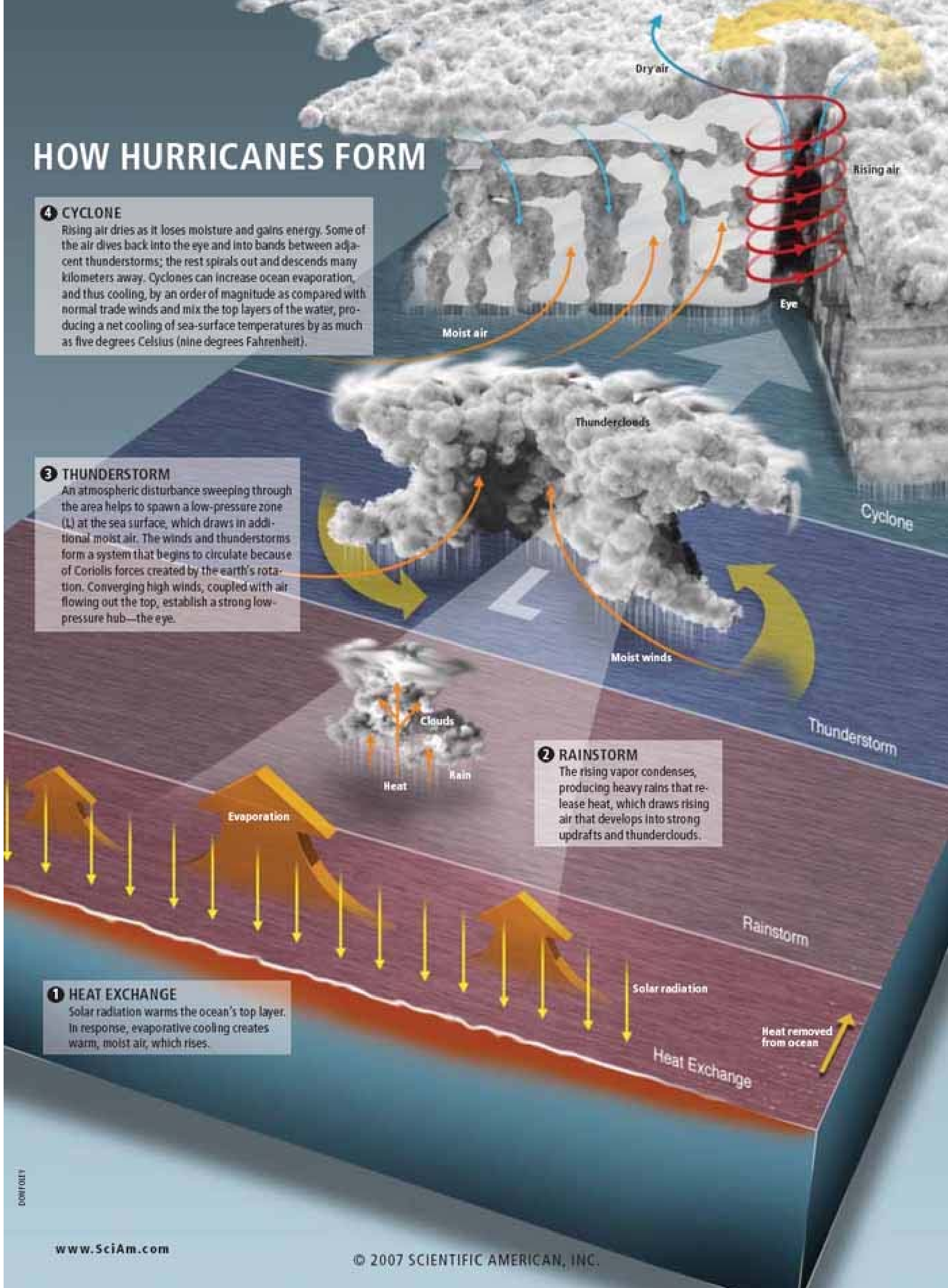
Dr. Kerry Emanuel from MIT, his book "The Divine Wind" is an excellent introduction to the world of hurricanes.

Hurricane's Science









A Simple Model of the Anatomy of a Hurricane

How tall is a hurricane?

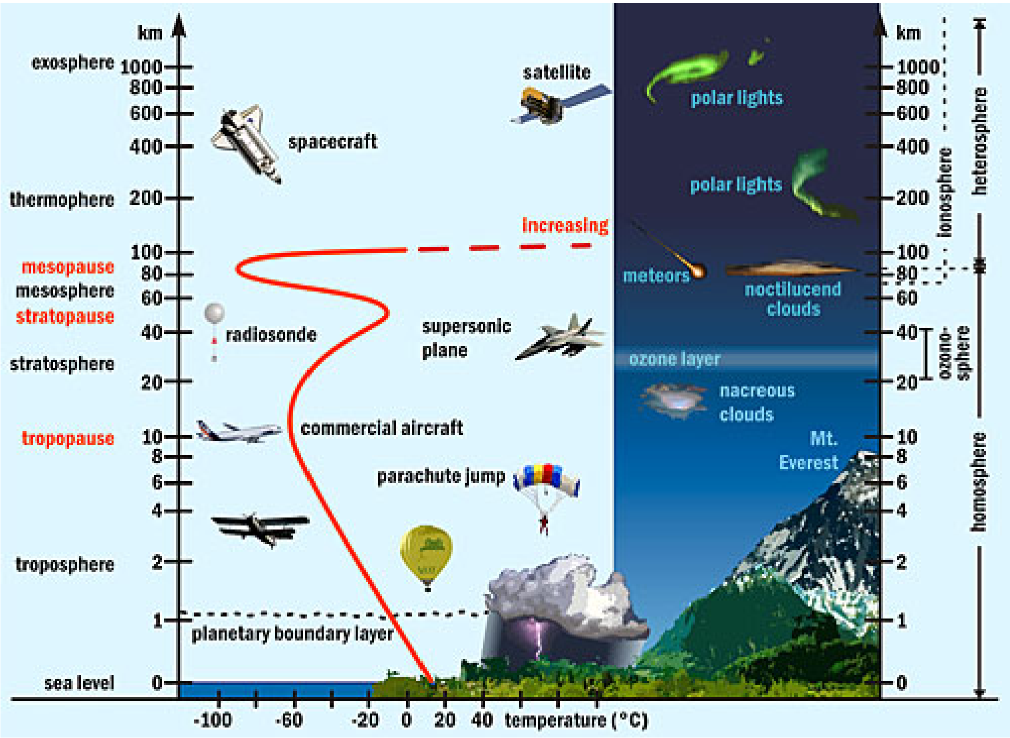
Let keep in mind that most of the clouds and storms will be located within the **troposphere**. Thus, in a first approximation the **top edge** for a hurricane might be considered the upper boundary of the troposphere, a number around **10 km**. Therefore, **hurricanes are more or less 10 km tall**.

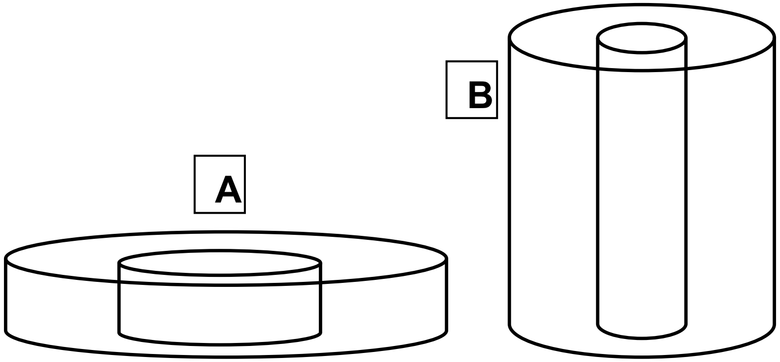
How wide they are?

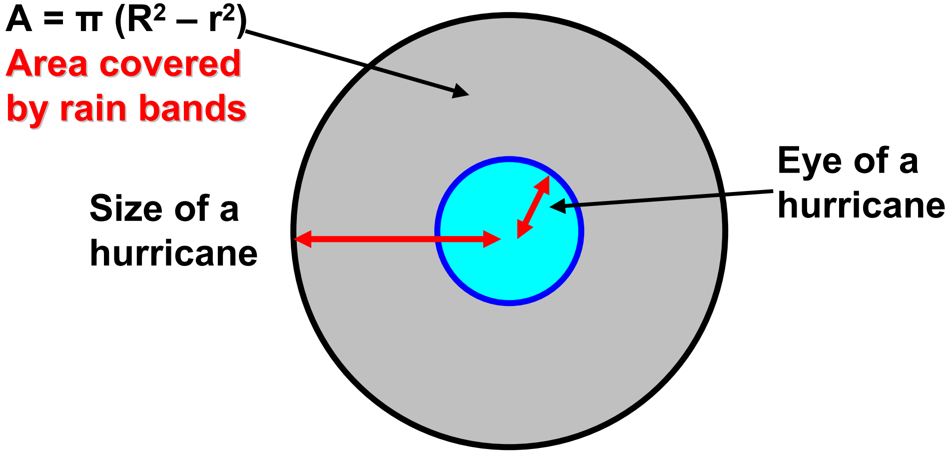
Typical hurricanes are considered those for which the distance from their center of circulation to their outermost closed isobar ranges between 3 and 6 latitude degrees, in other words, **hurricanes with a radius between 333 and 666 kilometers** (look at these numbers, interesting!!!).

With this information in mind, which picture illustrates better this situation?

The eye is normally circular in shape, and may range in size from 3 to 370 km (2 – 230 miles) in diameter.





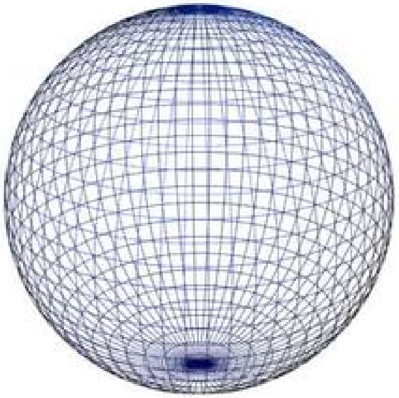


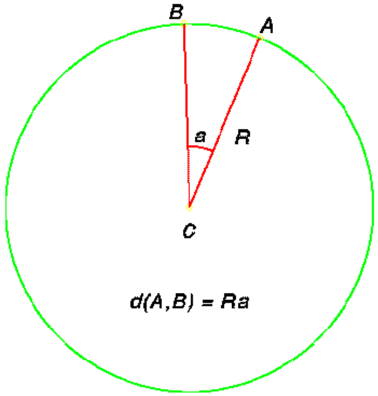
A Simple Model of the Anatomy of a Hurricane

Hurricane sizes are estimated by measuring the distance from their center of circulation to their outermost closed isobar.
If the radius (R) is:

- **Less than two degrees latitude, then the cyclone is "very small" or a midget.**
- **Radii of 2 – 3 degrees are considered "small". Radii between 3 and 6 latitude degrees are considered "average size".**
- **Tropical cyclones are considered "large" when the closed isobar radius is 6 – 8 degrees of latitude.**
- **"Very large" tropical cyclones have a radius of greater than 8 degrees.**

Hurricane size classification	Radius in Degrees Latitude	Radius in Km
Very Small or midget	Less than 2	
Small	Between 2 and 3	
Average size	Between 3 and 6	
Large	Between 6 and 8	
Very Large	Greater than 8	





The full circumference equals 360°. In order to convert degrees into units of distance a simple proportion is used:

$$\frac{Circumference}{360^0} = \frac{2\pi R}{360^o} = \frac{d(A,B)}{a}$$

A Simple Model of the Anatomy of a Hurricane

Hurricanes in a first approximation can be seen as hollow cylinders, where the inner core would represent the so called eye of the hurricane, and the outer cylindrical shell contains all rain bands. By using this simple model of a hurricane,

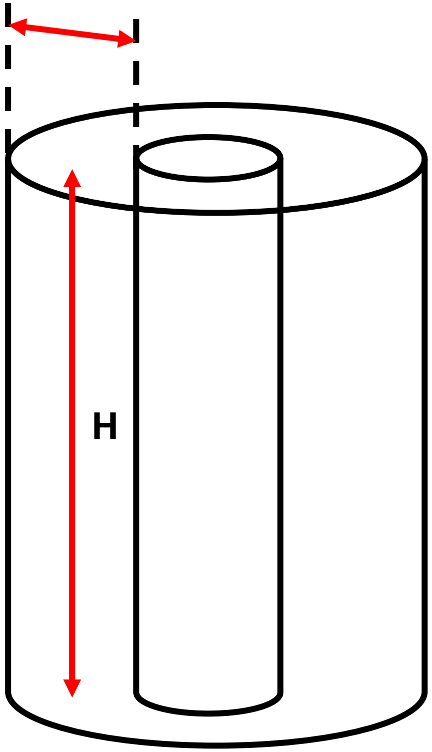
1. Find the volume occupied by rain bands (Hint: the volume of a cylinder is given by $V = \pi R^2 H$, where R is the radius, and H the height). For typical hurricanes (average size), the size of the inner core (eye of the hurricane) is around 50 mi .

2. By using the table provided in the Introduction, find out the approximate values for volumes of water contained in all of these three basins: Pacific Ocean, Atlantic Ocean, Caribbean and Gulf of Mexico. Once you have gotten these numbers, compare them with the volume occupied by rain bands found in the previous point (a). How many hurricanes these sizes are needed to fill out each one of these basins?

	Pacific Ocean	Atlantic Ocean	Caribbean and Gulf of Mexico
Volume			
# of hurricanes needed			

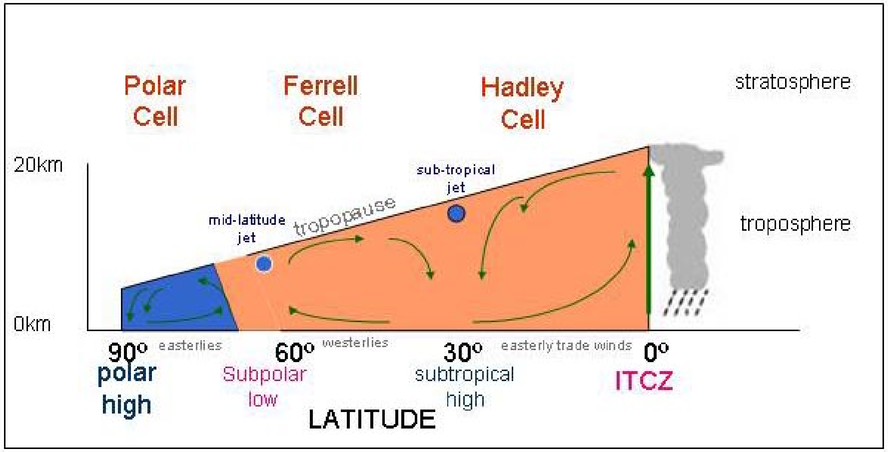
$A = \pi (R^2 - r^2)$

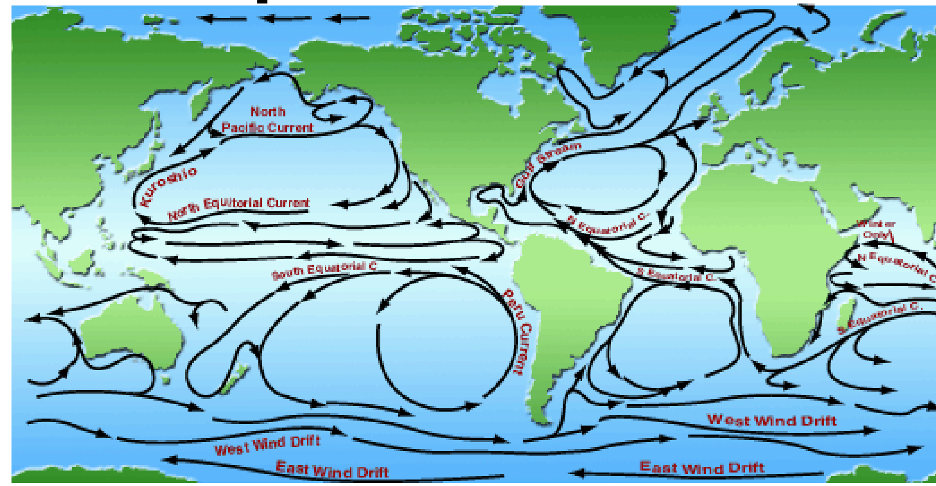
Area covered by rain bands

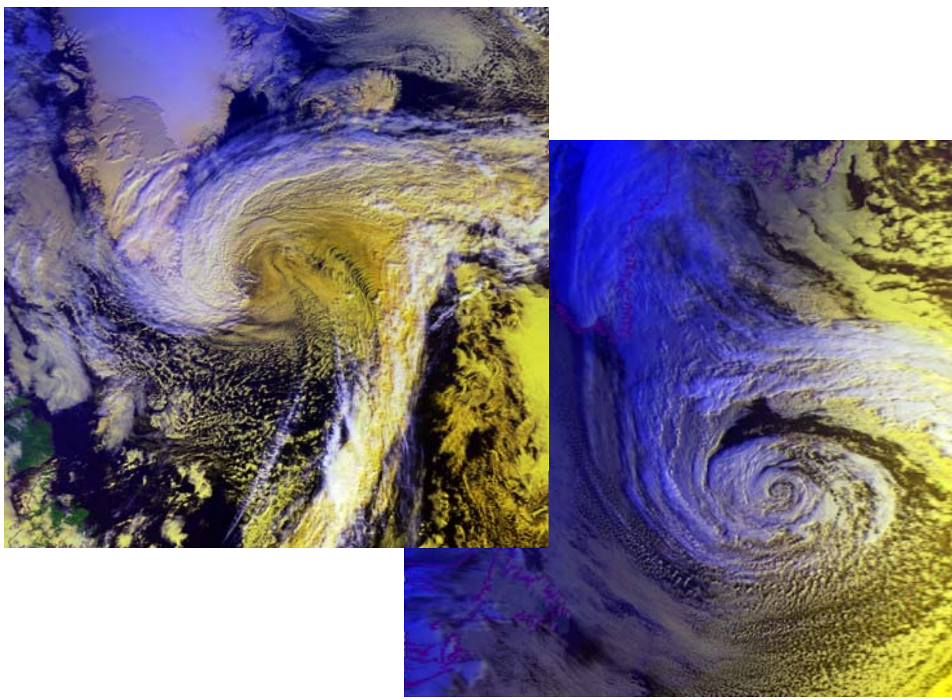


	Average	Depth	Area		Volume	
Ocean or Sea	**m**	**ft**	**10^6 km^2**	**10^6 mi^2**	**10^6 km^3**	**10^6 mi^3**
Pacific Ocean	4,300	14,000	155.6	60.1	679.6	163.1
Atlantic Ocean	3,900	12,900	76.8	30	313.4	75.2
Indian Ocean	3,900	12,800	68.5	26.5	269.3	64.7
Gulf of Mexico and Caribbean Sea	2,200	7,300	4.3	1.7	9.6	2.3
Artic Ocean	1,300	4,300	14.1	5.4	17	4.1
Hudson Bay	101	331	1.2	0.5	0.16	0.04
Baltic Sea	55	180	0.4	0.2	0.02	0.005
Mediterranean and Black Sea	1430	4,690	3.0	1.1	4.2	1
World Ocean	3790	12,430	361.1	139.4	1,370	329

Energy transport







http://www.crh.noaa.gov/mqt/webpics/weatherpics/Big/thunderstorm%201.jpg

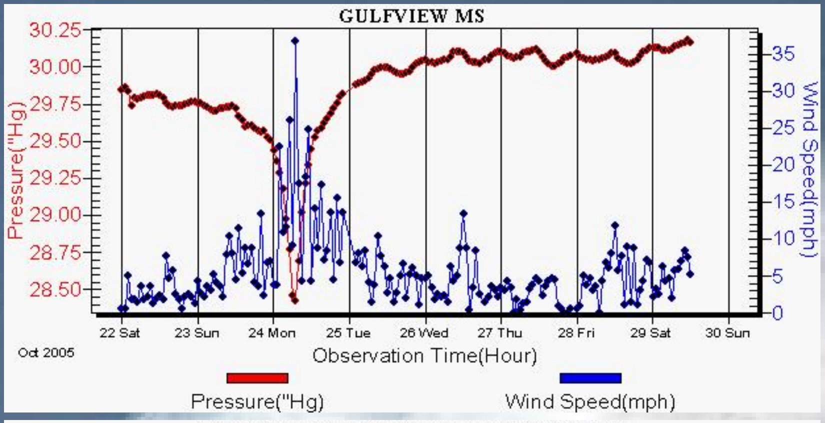
http://www.onr.navy.mil/focus/ocean/motion/currents1.htm

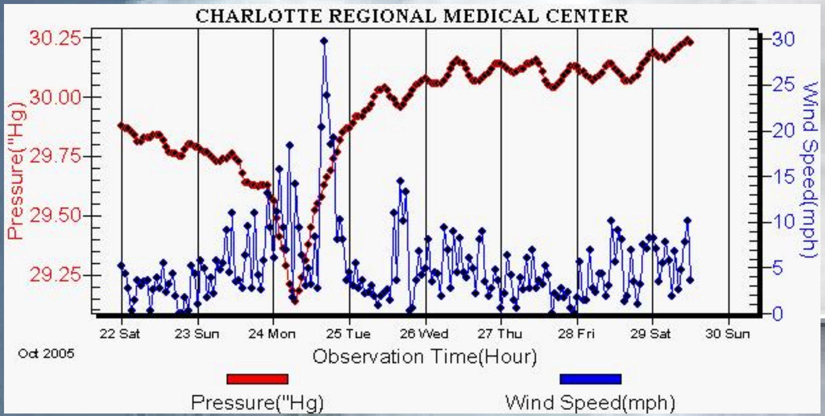
Saffir-Simpson scale
Inequalities at work – Saving life of people!!!

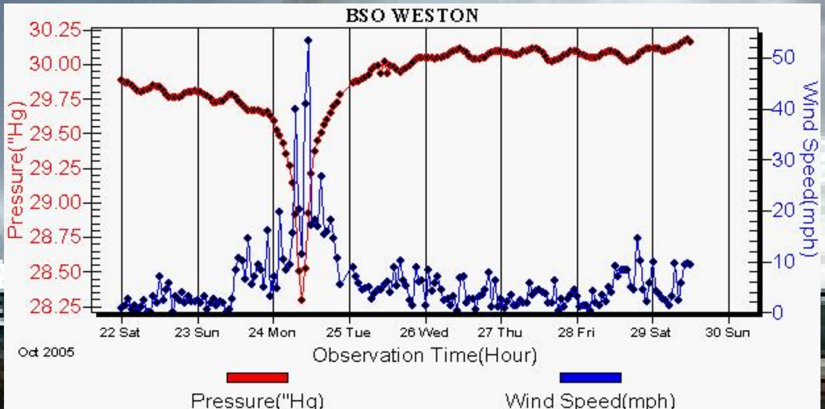
Category	Central Pressure mb (inches of Hg)	Wind Speed mp/h	Storm Surge ft (m)	Damage
TD	> 990 (> 29.25)	< 39		
TS	> 985 (> 29.04)	39 – 73		
H 1	> 980 (> 28.94)	74 – 95	4 – 5 (~1.5)	Damage mainly trees, shrubbery, and unanchored mobile homes
H 2	965 – 980 (28.50 – 28.93)	96 – 110	6 – 8 (2 – 2.5)	Some trees blown down; major damage to exposed mobile homes; some damage to roofs of buildings
H 3	945 – 965 (27.91 – 28.49)	111 – 130	9 – 12 (2.5 – 4)	Foliage removed from trees, large trees blown down; mobile homes destroyed; some structural damage to small buildings
H 4	920 – 945 (27.17 – 27.90)	131 – 155	13 – 18 (4 – 5.5)	All signs blown down; extensive damage to roofs; complete destruction of mobile homes; flooding inland as far as 10 km (6mi); major damage to lower floors of structures near shore
H 5	< 920 (< 27.17)	> 155	> 18 (> 5.5)	Severe damage to windows and doors; extensive damage to roofs of homes and industrial buildings; small buildings overturned and blown away; major damage to lower floors of all structures less than 4.5 m (15ft) above sea level within 500 m of shore

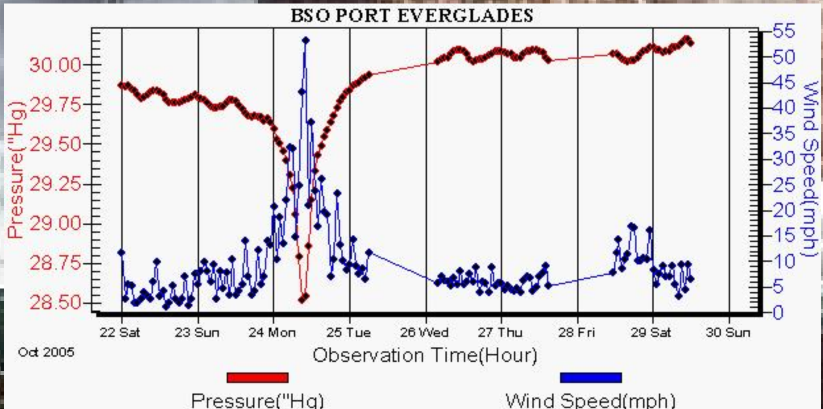
Wind Hazards

Variation of the barometric pressure during as a function of time for a moving hurricane





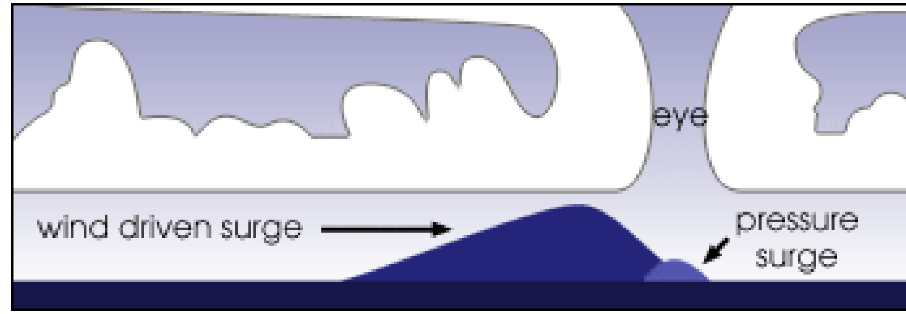




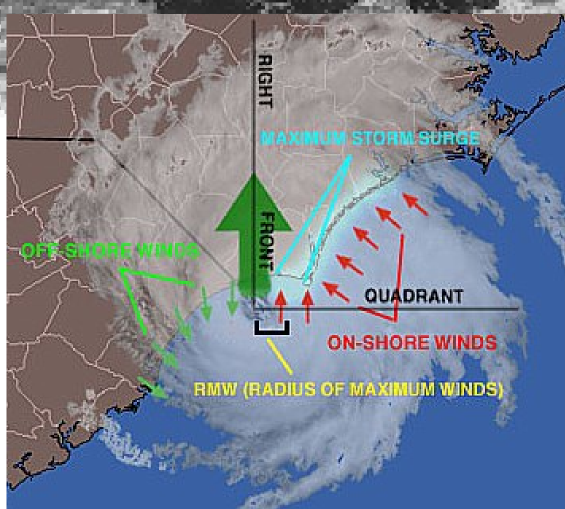
Storm Surge

The greatest potential for loss of life in a hurricane is from the <u>storm surge</u>.

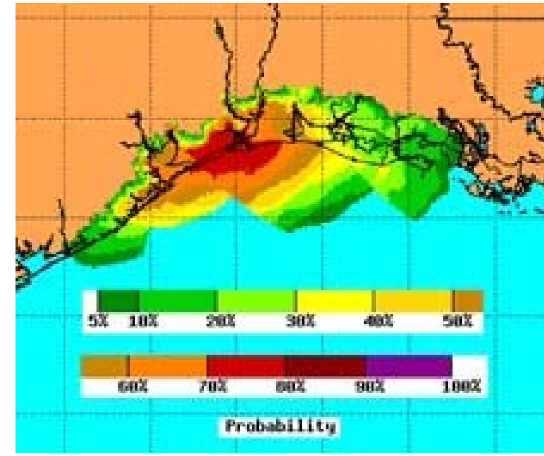
Historically, the storm surge has claimed nine of ten victims in hurricanes.

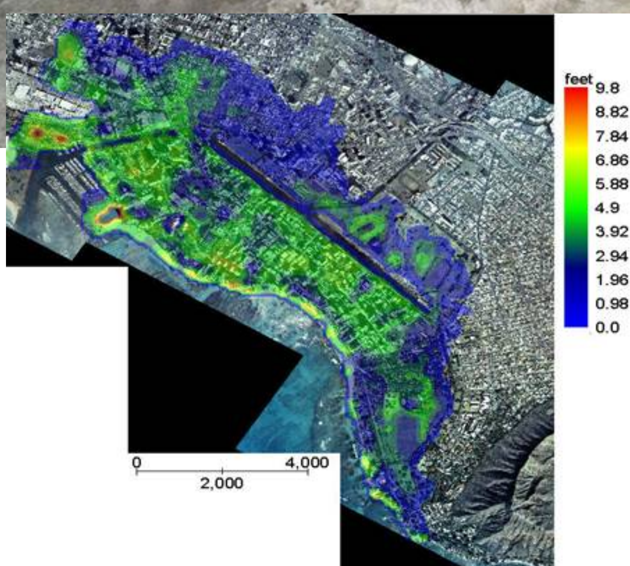


Hurricane Camille, 1969

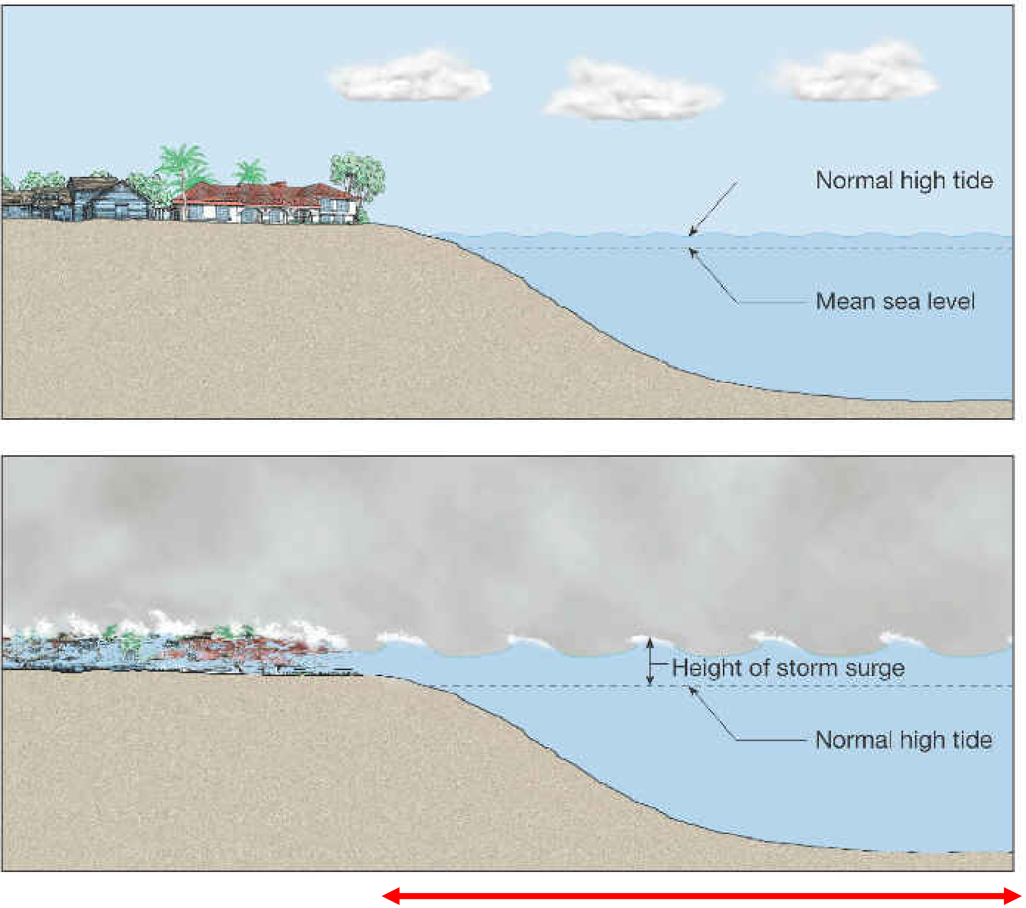


FLEEING HURRICANE GEORGES IN KEY WEST

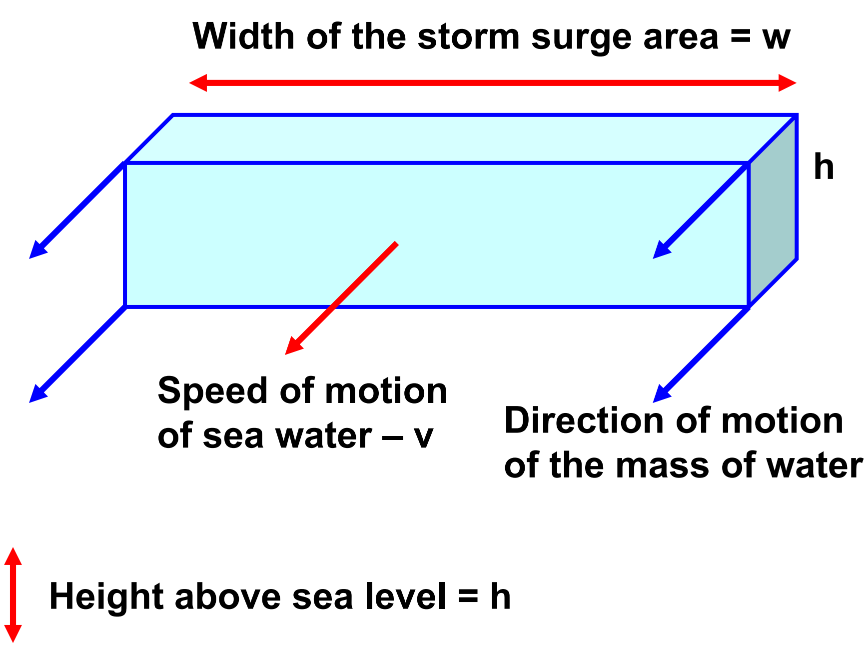




How to estimate the force exerted by the mass of water in the storm surge?



Depth of the storm surge area = d



Volume of the mass of sea water = V

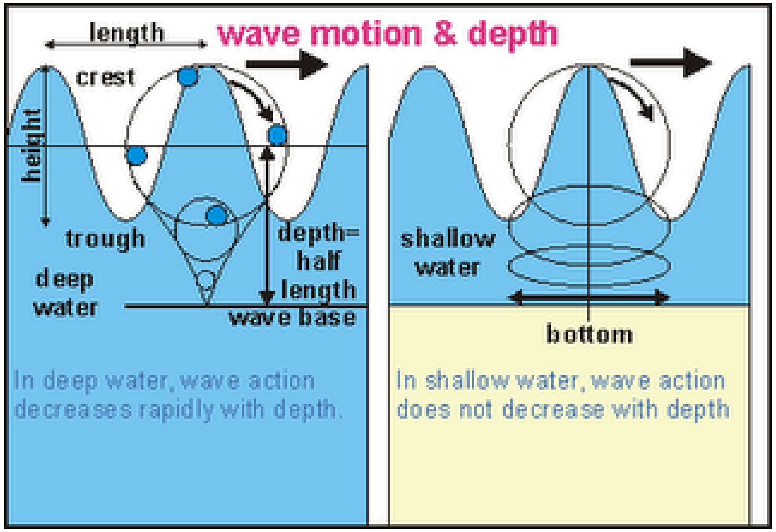
V = w d h

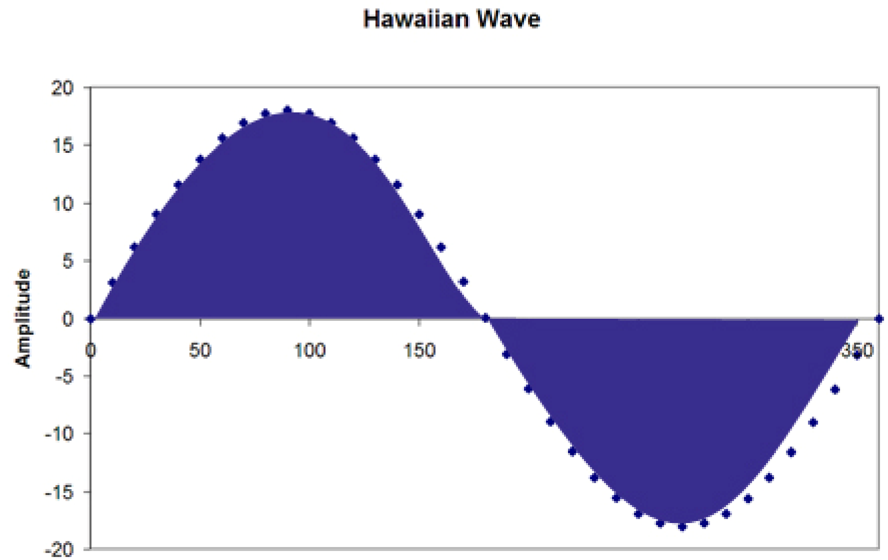
The net force produced by this Mass of water equals:

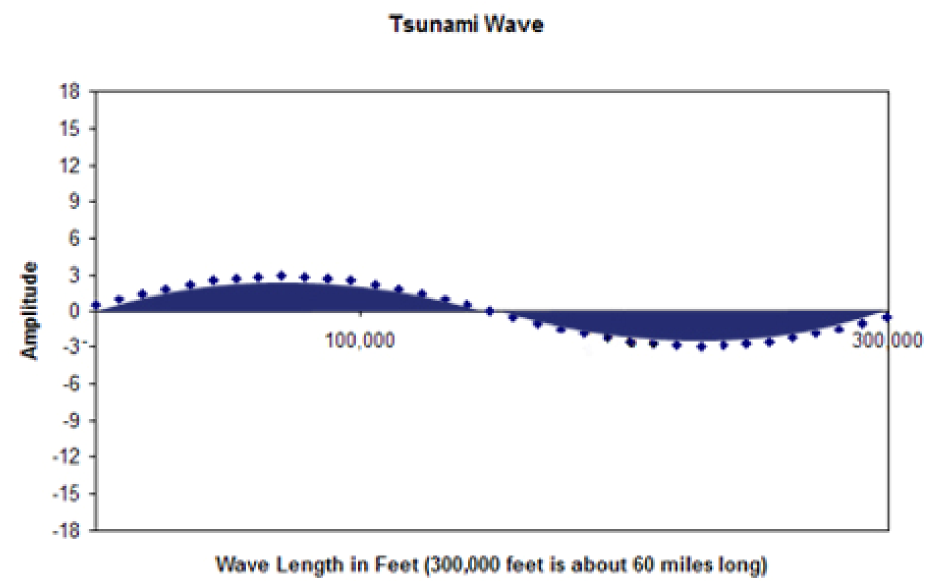
$$F = \frac{1}{2}\rho g w h^2$$

Urban areas located near the coast will Suffer the impact of the storm surge forces. If building are not made such that, they may afford a high load on their walls, then, they will collapse after the impact.

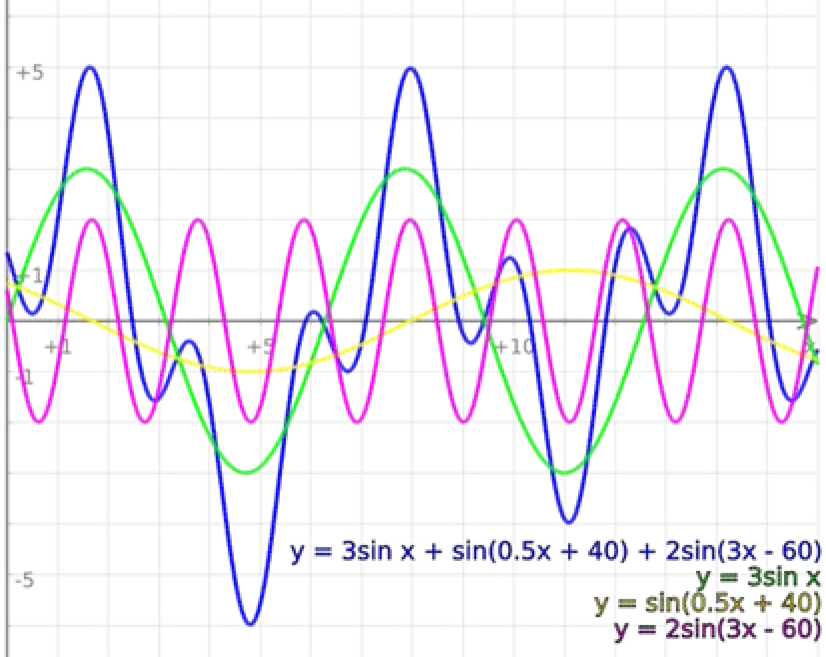
Sea waves and its mathematical representation: Trigonometric functions at work



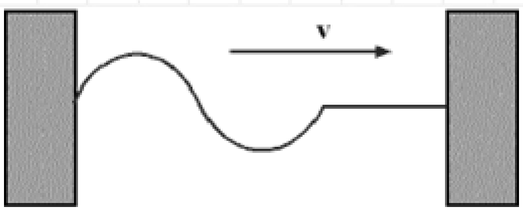




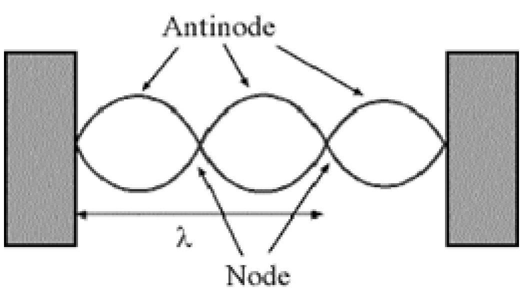
Building a family of trigonometric functions

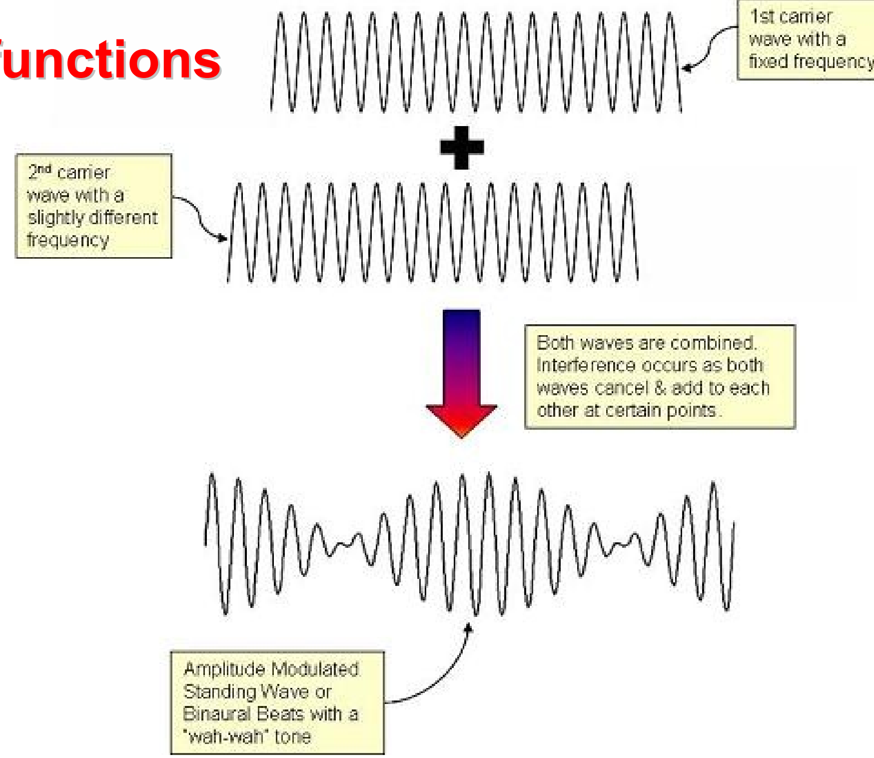


Traveling Wave



Standing Wave





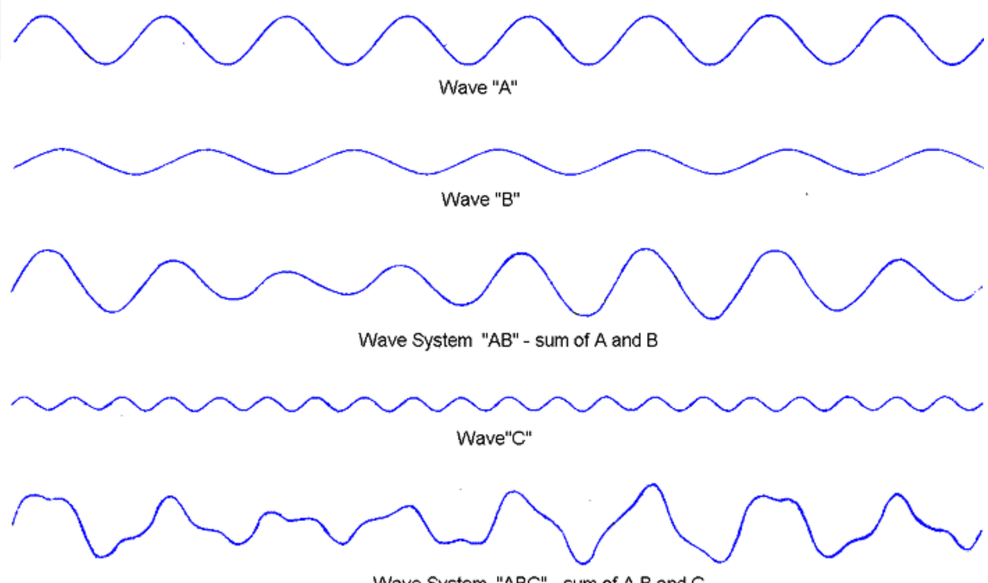
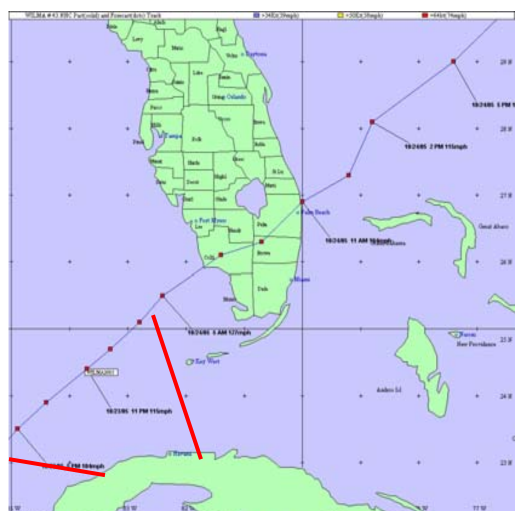


Figure 2 - How simple waves add together to form a random sea.
Note: Wave height/length ratios are greatly exaggerated for clarity.

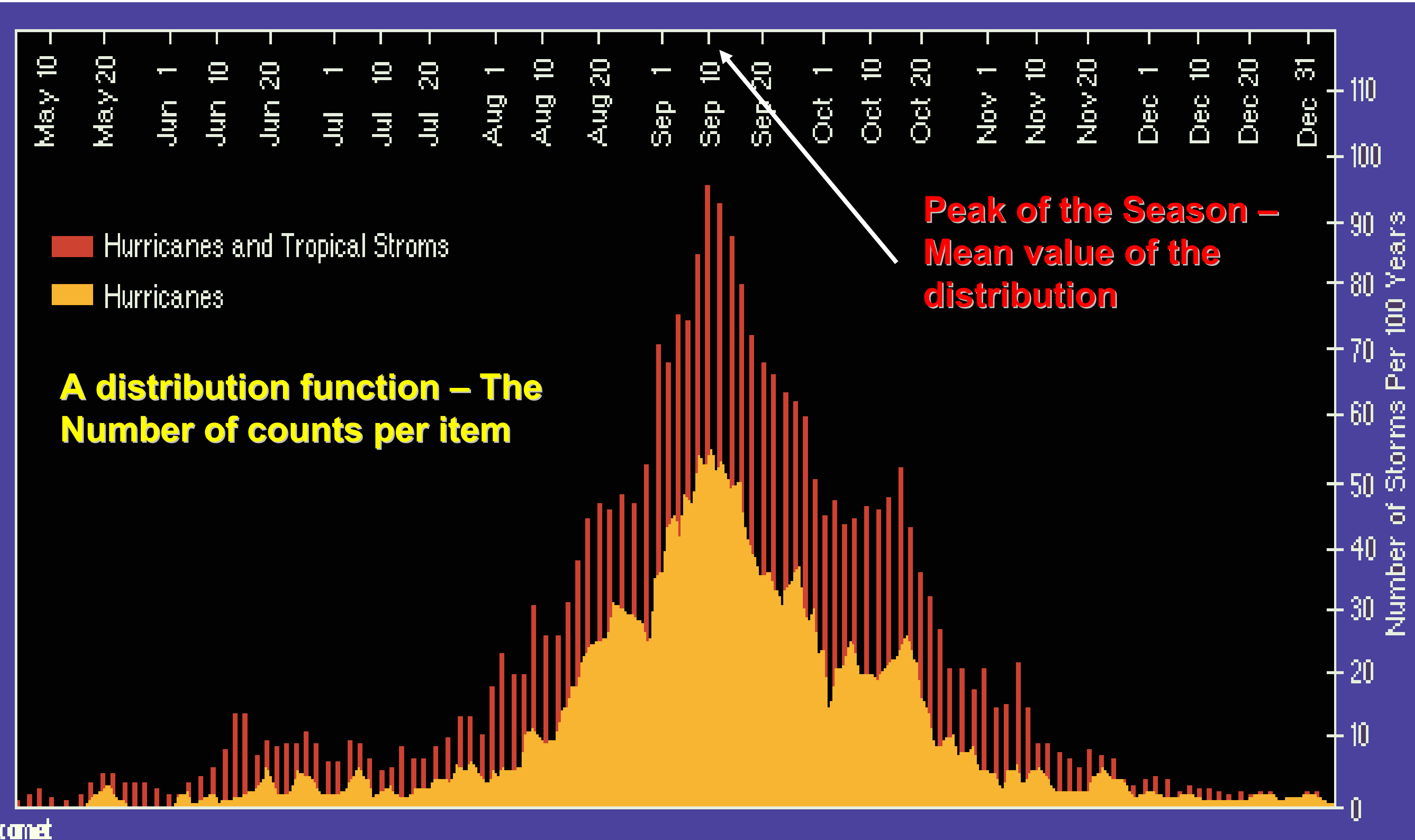
Conditions Necessary for a Fully Developed Sea at Given Winds Speeds

Wind Conditions			Wave Size		
Wind Speed in One Direction	**Fetch**	**Wind Duration**	**Average Height**	**Average Wavelength**	**Average Period**
19 km/hr **12 mi/hr**	**19 km** **12 mi**	**2 hr**	**0.27 m** **0.9 ft**	**8.5 m** **28 ft**	**3.0 sec**
37 km/hr **23 mi/hr**	**139 km** **86 mi**	**10 hr**	**1.5 m** **4.9 ft**	**33.8 m** **111 ft**	**5.7 sec**
56 km/hr **35 mi/hr**	**518 km** **322 mi**	**23 hr**	**4.1 m** **13.6 ft**	**76.5 m** **251 ft**	**8.6 sec**
74 km/hr **46 mi/hr**	**1313 km** **816 mi**	**42 hr**	**8.5 m** **27.9 ft**	**136 m** **446 ft**	**11.4 sec**
92 km/hr **58 mi/hr**	**2627 km** **1633 mi**	**69 hr**	**14.8 m** **48.7 ft**	**212.2 m** **696 ft**	**14.3 sec**

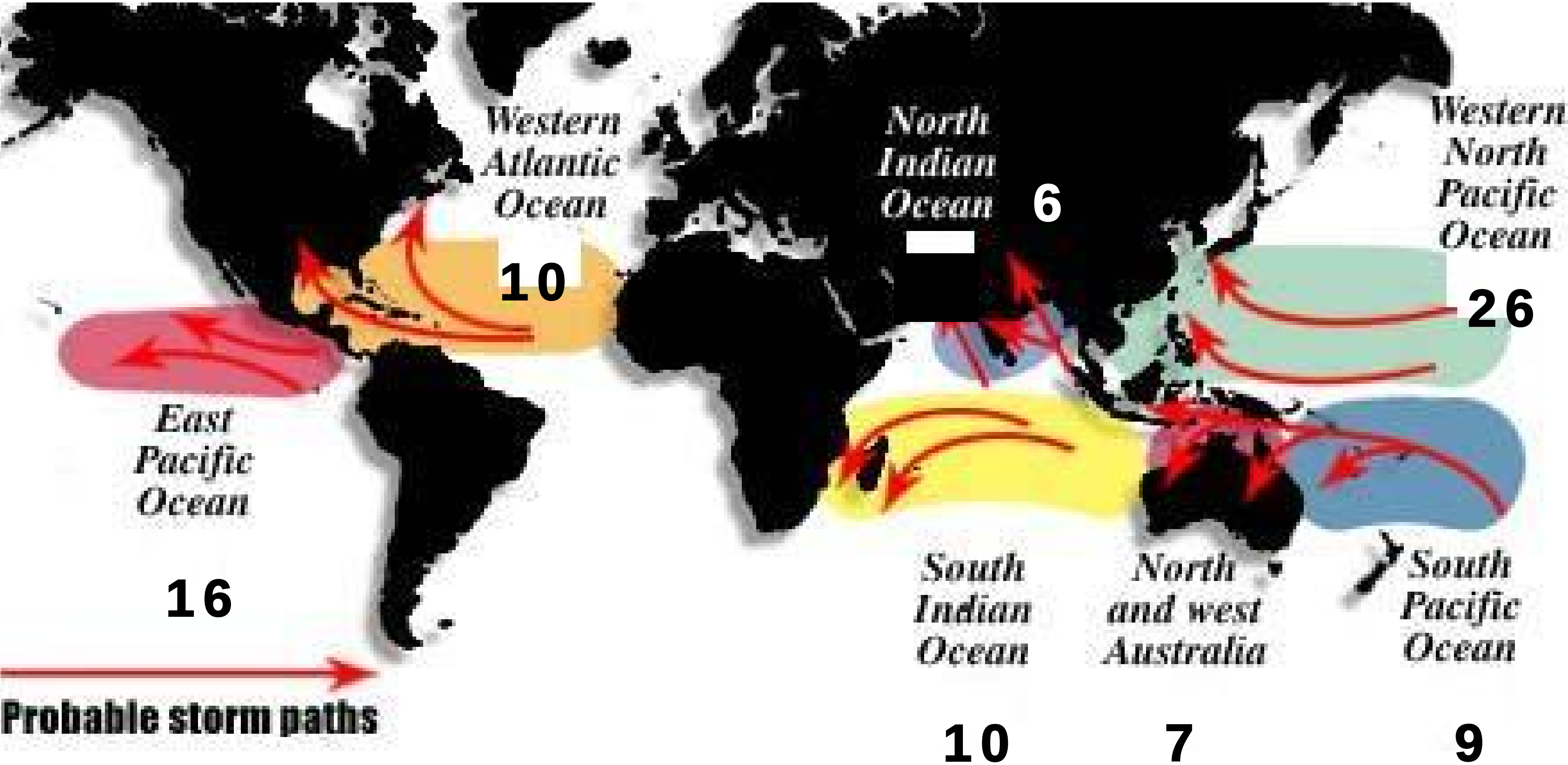


Storm wave trains in Havana, Cuba due to Wilma)

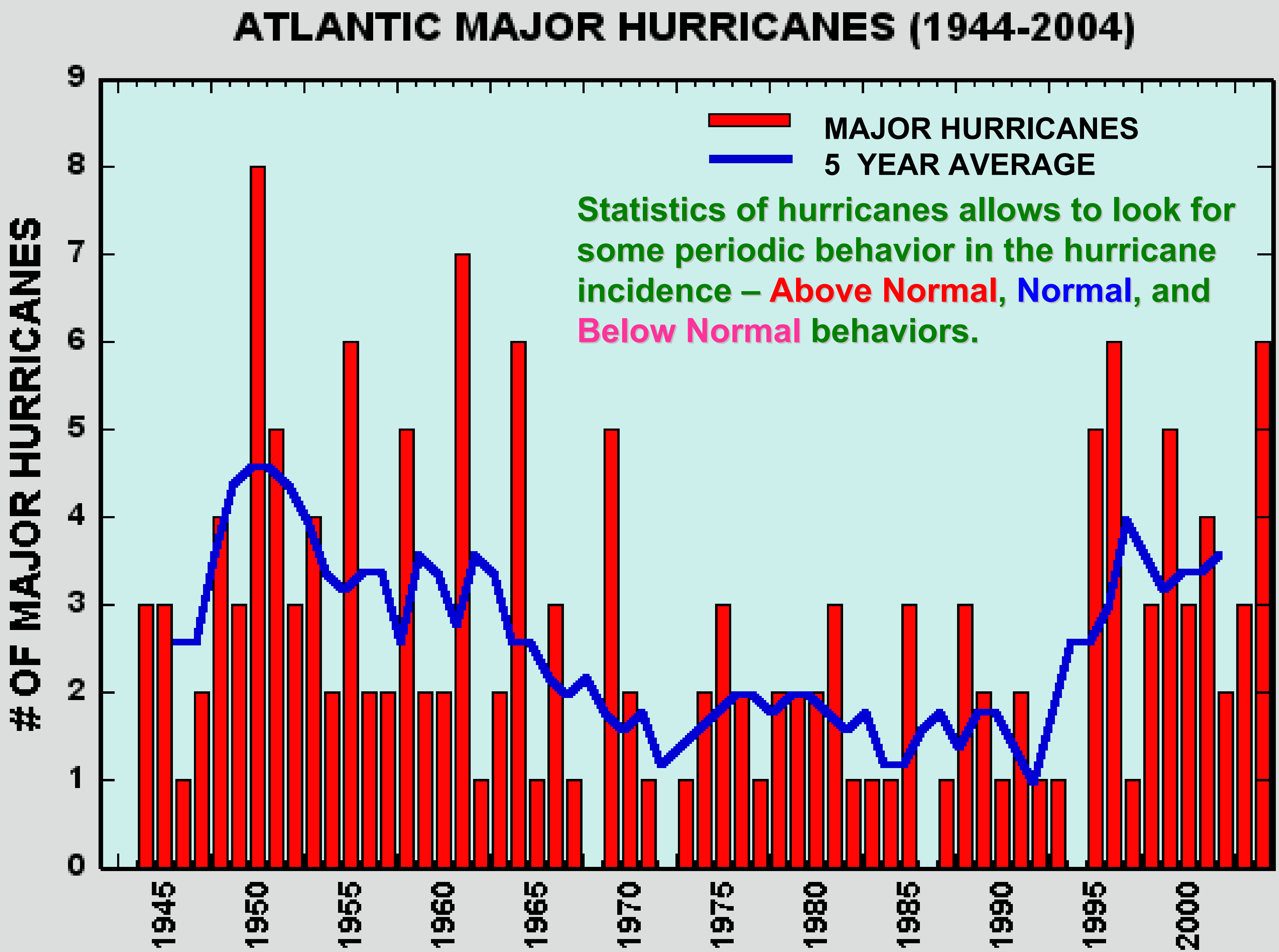
Atlantic Hurricane Basin Climatology: Mean, Median, Mode



Global Tropical Cyclones



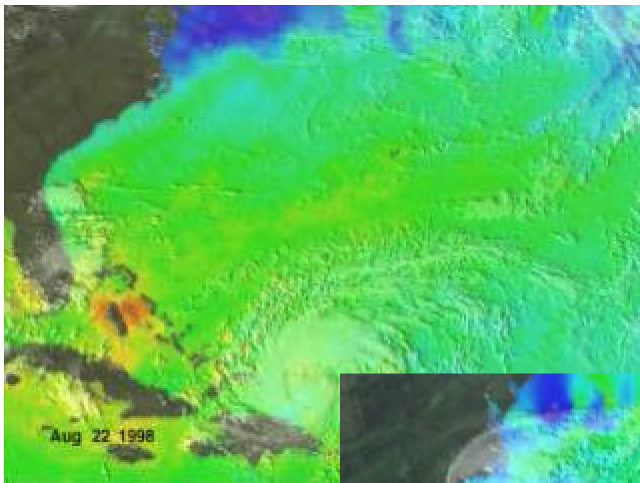
Average: 84 Per Year World Wide


ATLANTIC MAJOR HURRICANES (1944-2004)
OF MAJOR HURRICANES
0
1
2
3
4
5
6
7
8
9
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
MAJOR HURRICANES
5 YEAR AVERAGE
Statistics of hurricanes allows to look for some periodic behavior in the hurricane incidence – Above Normal, Normal, and Below Normal behaviors.

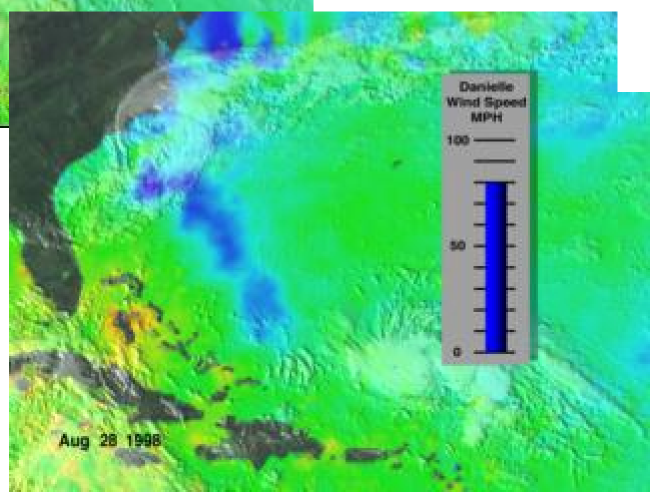
Ocean impacts

The hurricane brings colder ocean water into the box (both from below, and from upstream)

Before

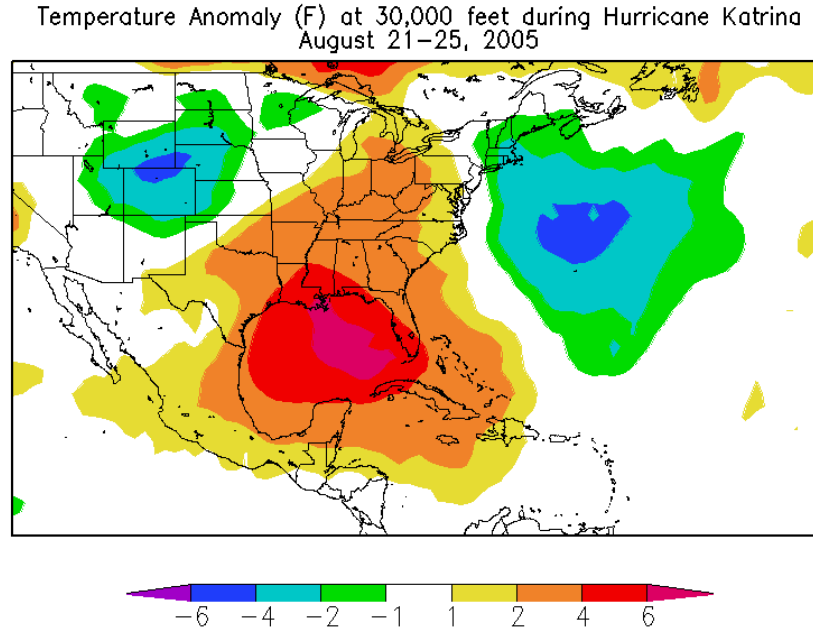


After



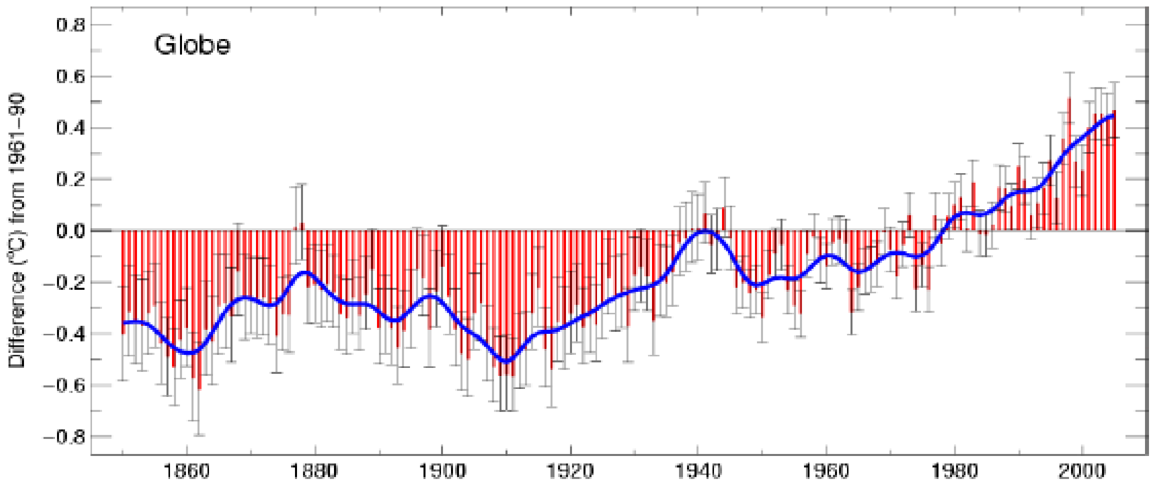
Imagery courtesy of GSFC/NASA: http://svs.gsfc.nasa.gov/vis/a000000/a001000/a001066/

Atmosphere impacts

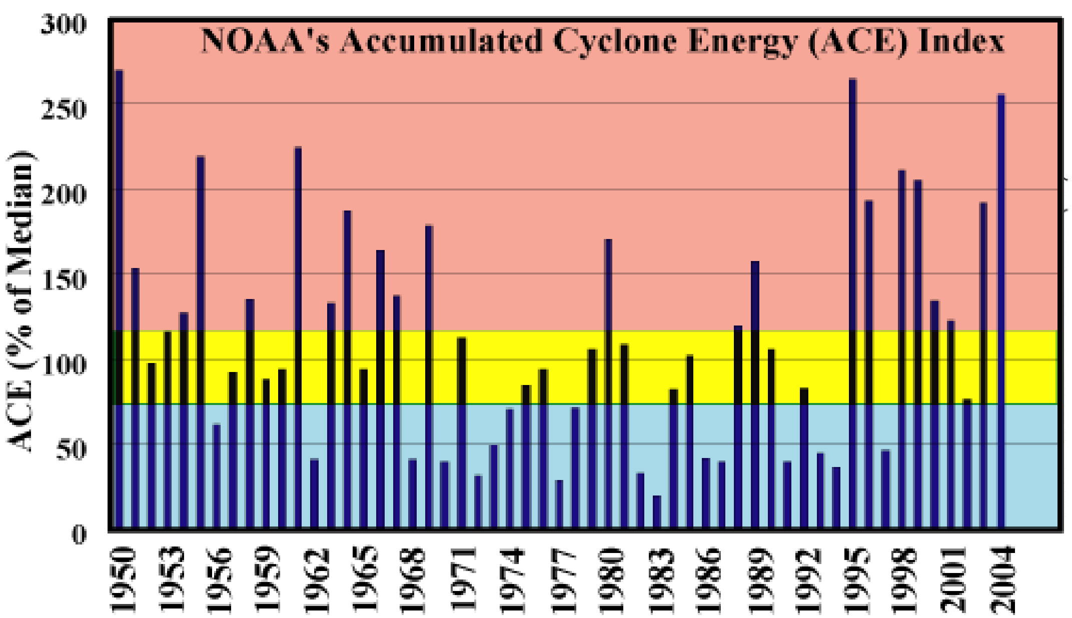


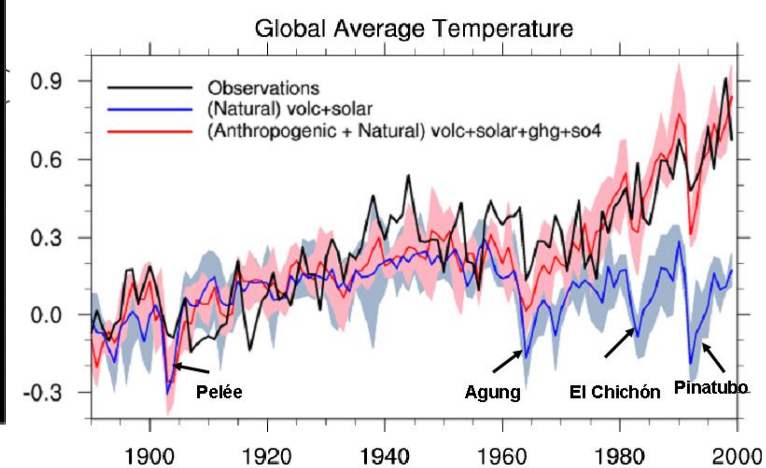
Example: The week after hurricane Gloria (1985) impacted New England, it arrived as an intense fall storm in Europe. The 4th of October, 1985 was the warmest day in the 20th century in Switzerland (NHC)

Causes of Global Surface Temperature Variability

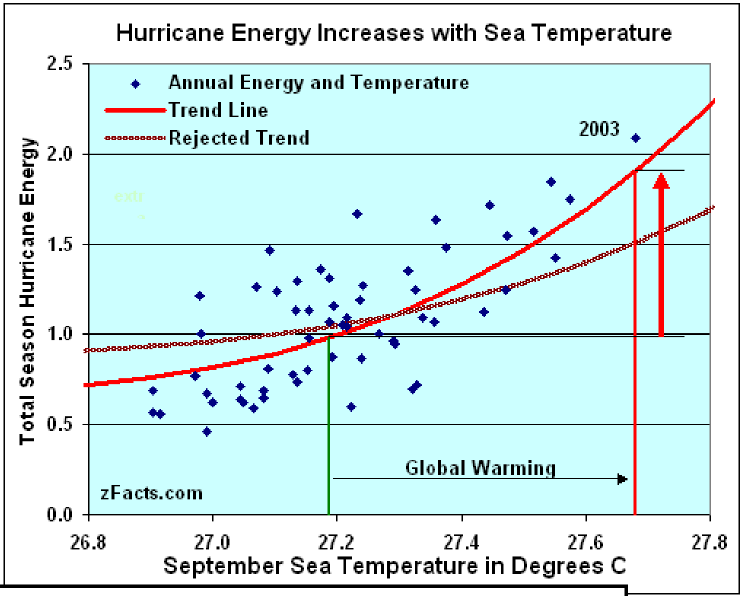


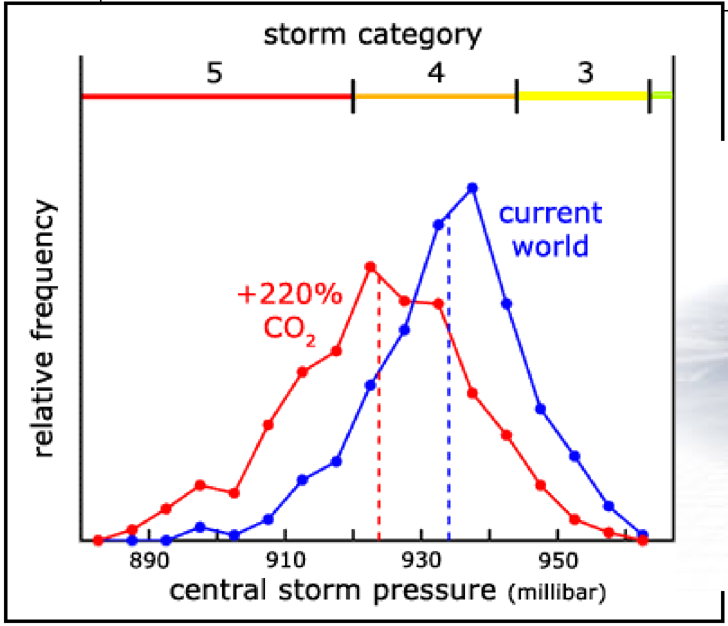
- 1910's through 1930's: decreasing volcanic activity and increasing greenhouse gases contributed to a warming trend
- 1940's through 1970's: as industrial activity increased, sun-blocking sulfates and other aerosols from both volcanic and anthropogenic sources contributed to a slight cooling
- Since 1980: the increase in anthropogenic greenhouse gas emissions has overwhelmed the aerosol effect to produce global warming

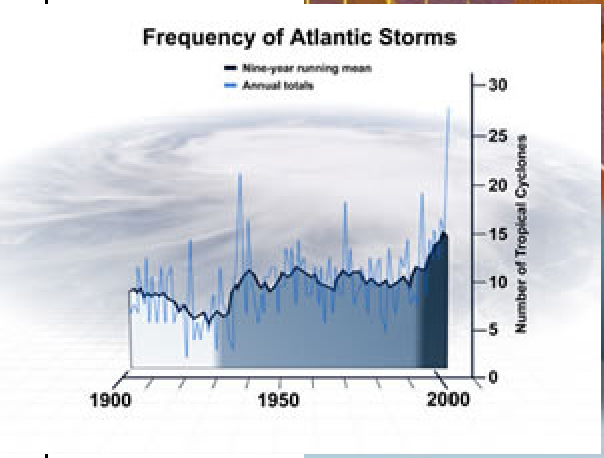


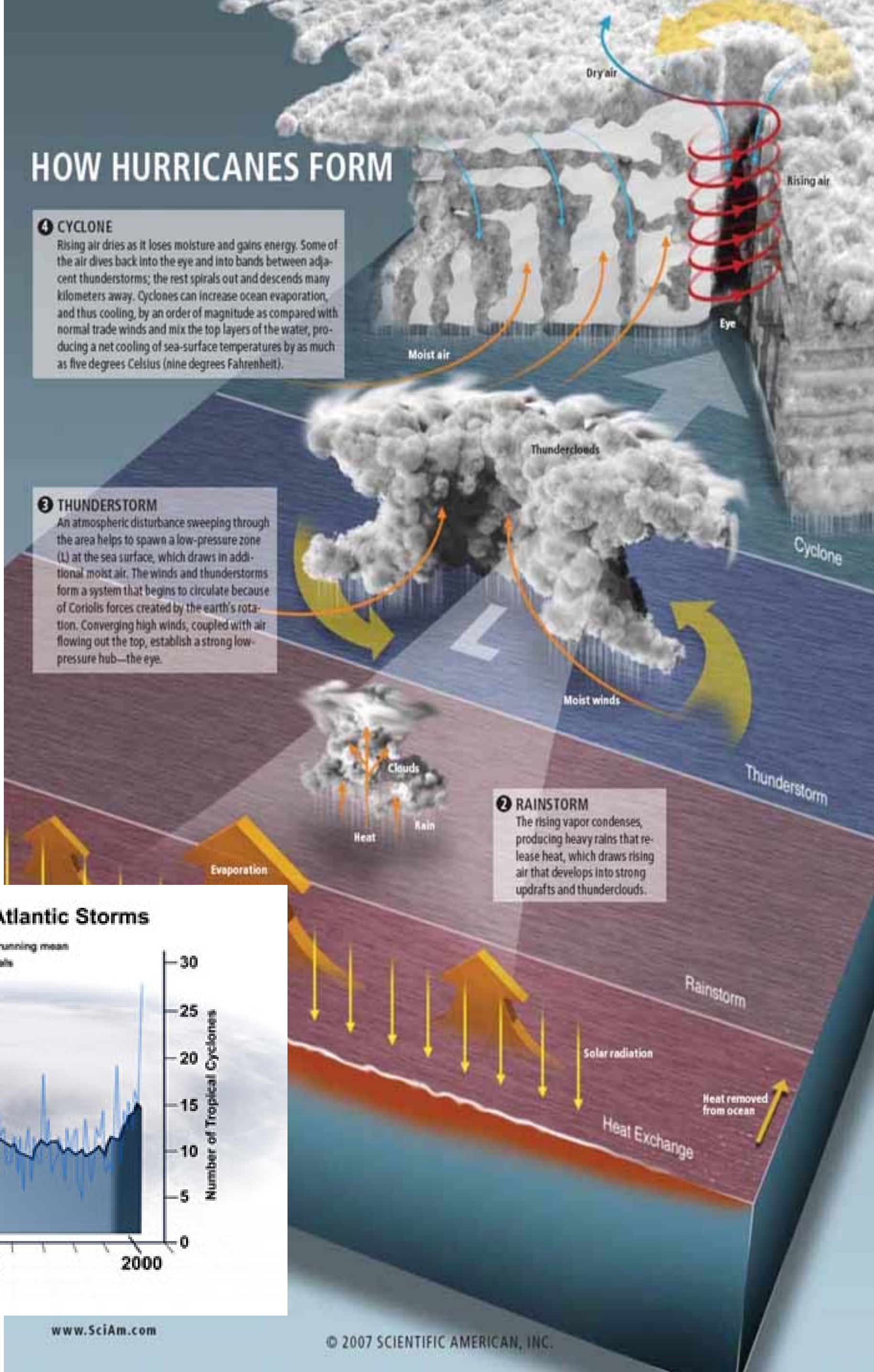


How far Global Climate Changes may affect the genesis and the dynamics of hurricanes worldwide?



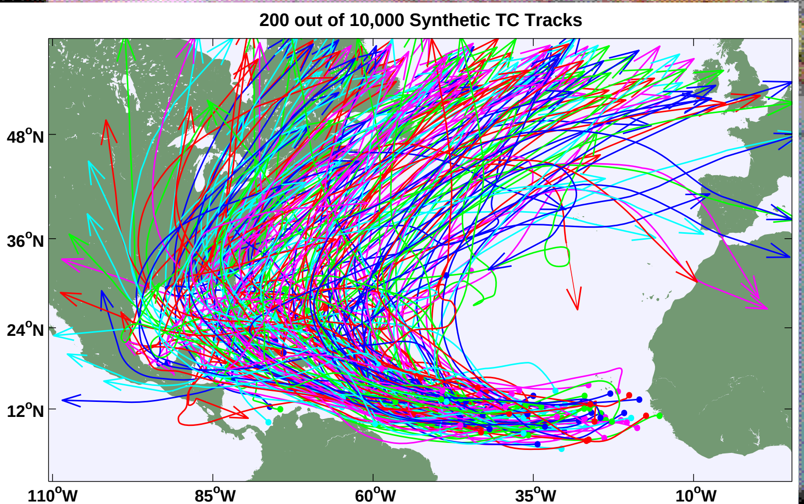




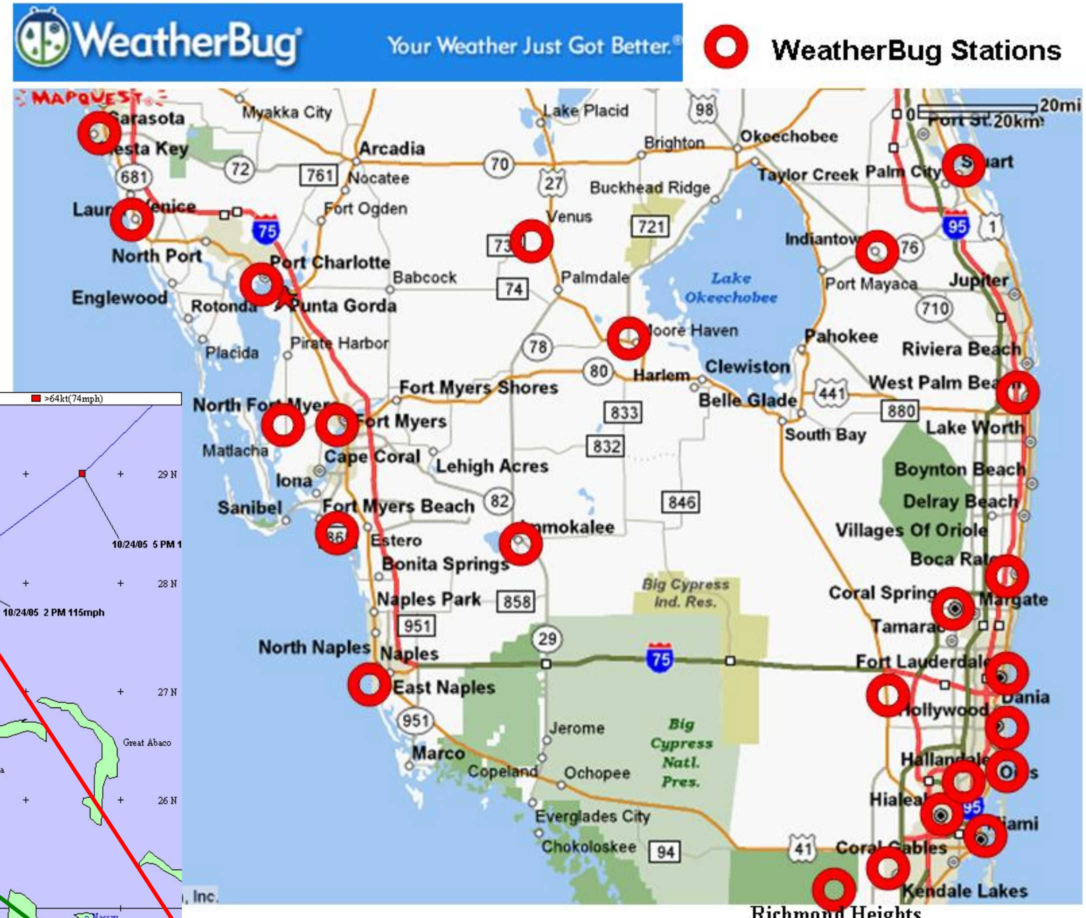


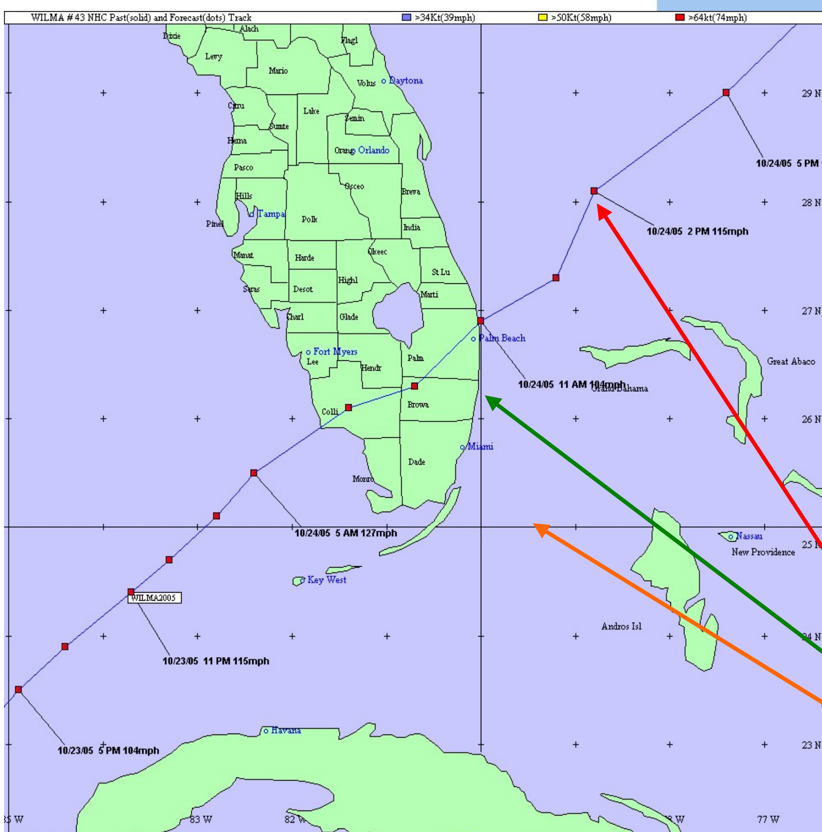
Climatological Tracks of Atlantic Basin Tropical Cyclones

Most of the Hurricanes follow a parabolic path that can be a motivation for Algebra



Tracking a Hurricane: Domain and Range

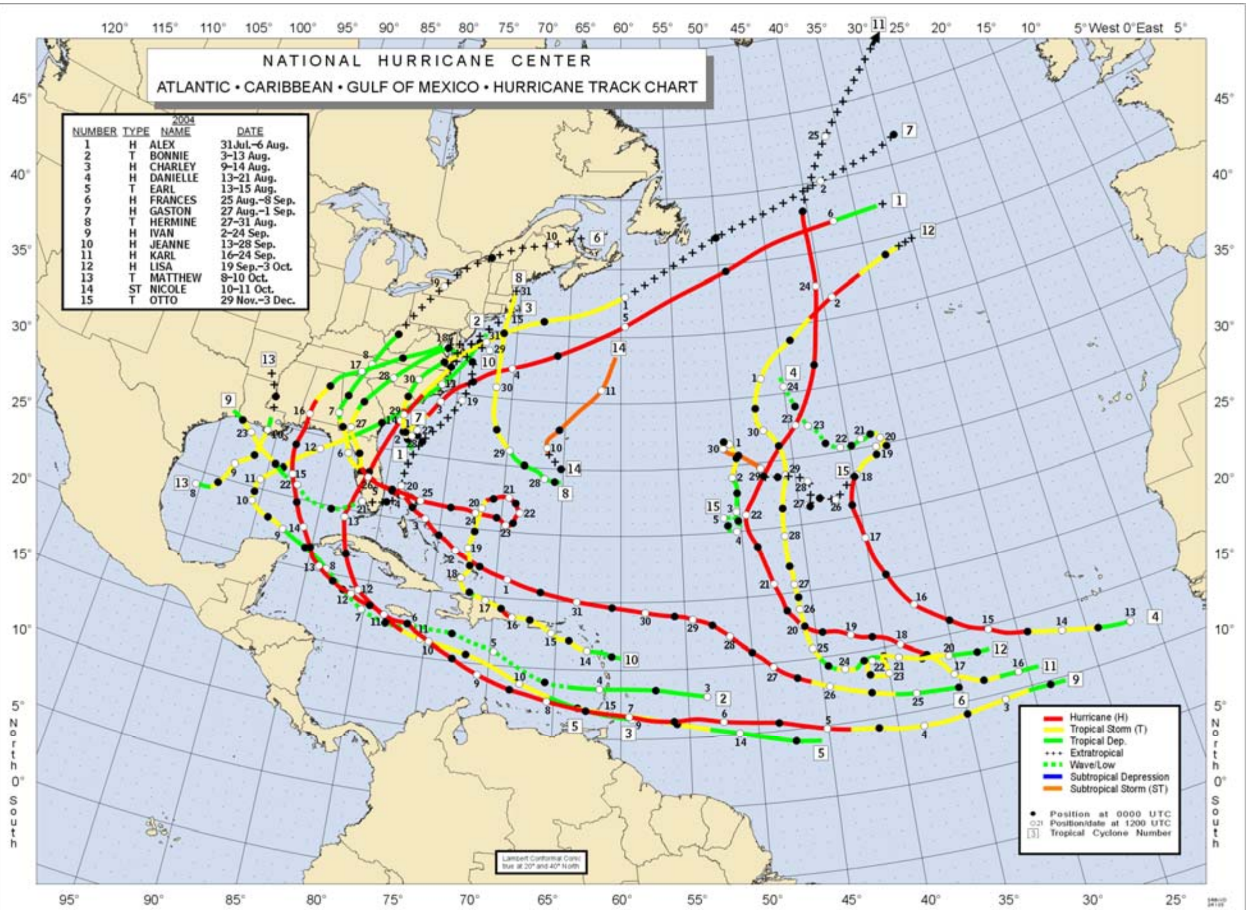


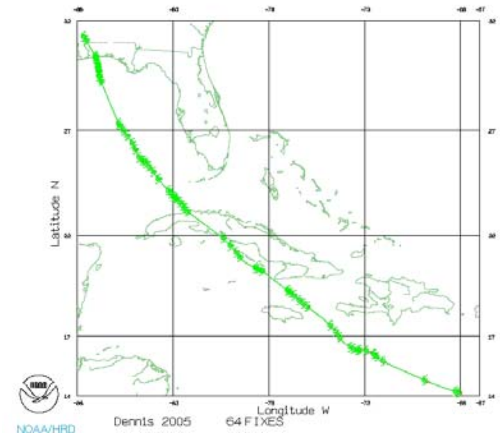


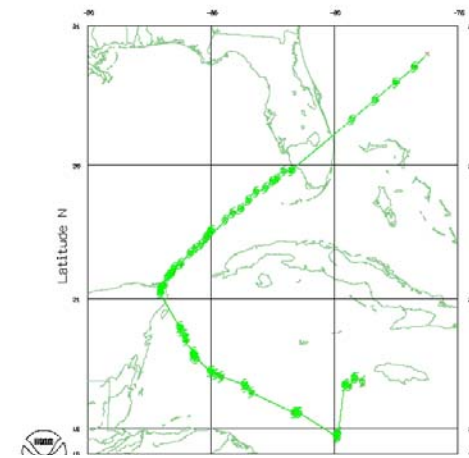
A point with coordinates (x,y) where
X is the Longitude and Y the Latitude

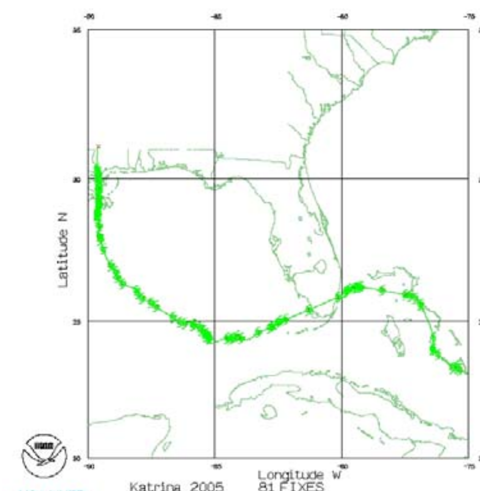
The domain of the hurricane's track
Is the collection of all longitudes, while
The range is the collection of latitudes.

Hurricane's Tracks







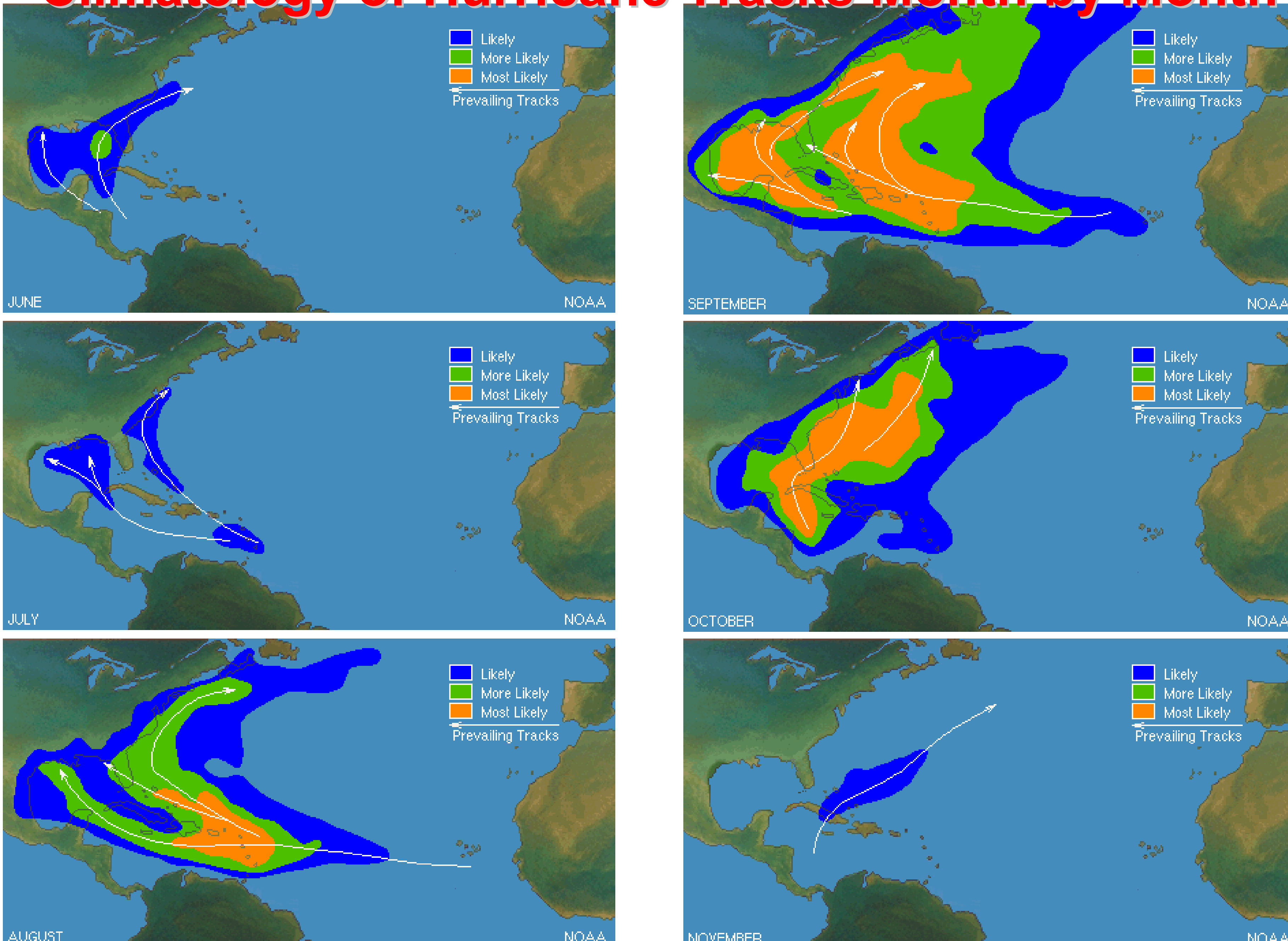


Possible tracks:

- A line – $y = mx + b$
- A parabola – $x = ay^2 + by + c$
- A cubic curve
- A curve with a loop

Is there any correlation between the kind of a curve a hurricane's track will follow and the weather or season?

Climatology of Hurricane Tracks Month by Month



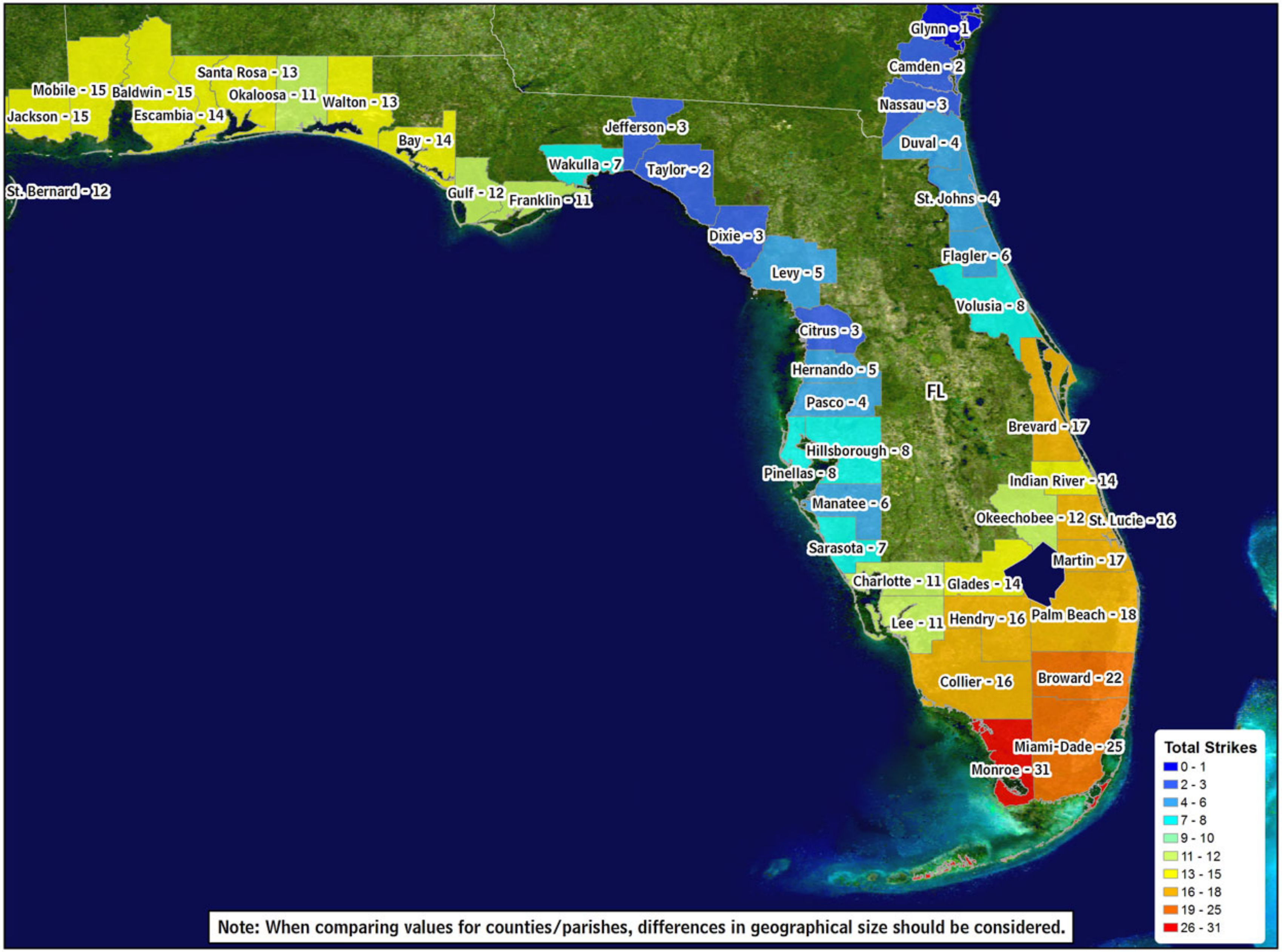
Hurricane Data Base

Month / Track	Line	Parabola	Cubic	Other
June				
July				
August				
September				
October				
November				

Work in teams and follow the steps

1. **Pick a month**
2. **Go to** http://www.aoml.noaa.gov/hrd/hurdat/DataByYearandStorm.htm **and analyze the latest 30 years for every month. Count how many times in a Month the track is either a line, or a parabola, or a cubic function or something else.**
3. **Create a histogram summarizing your findings. Try to explain your results.**

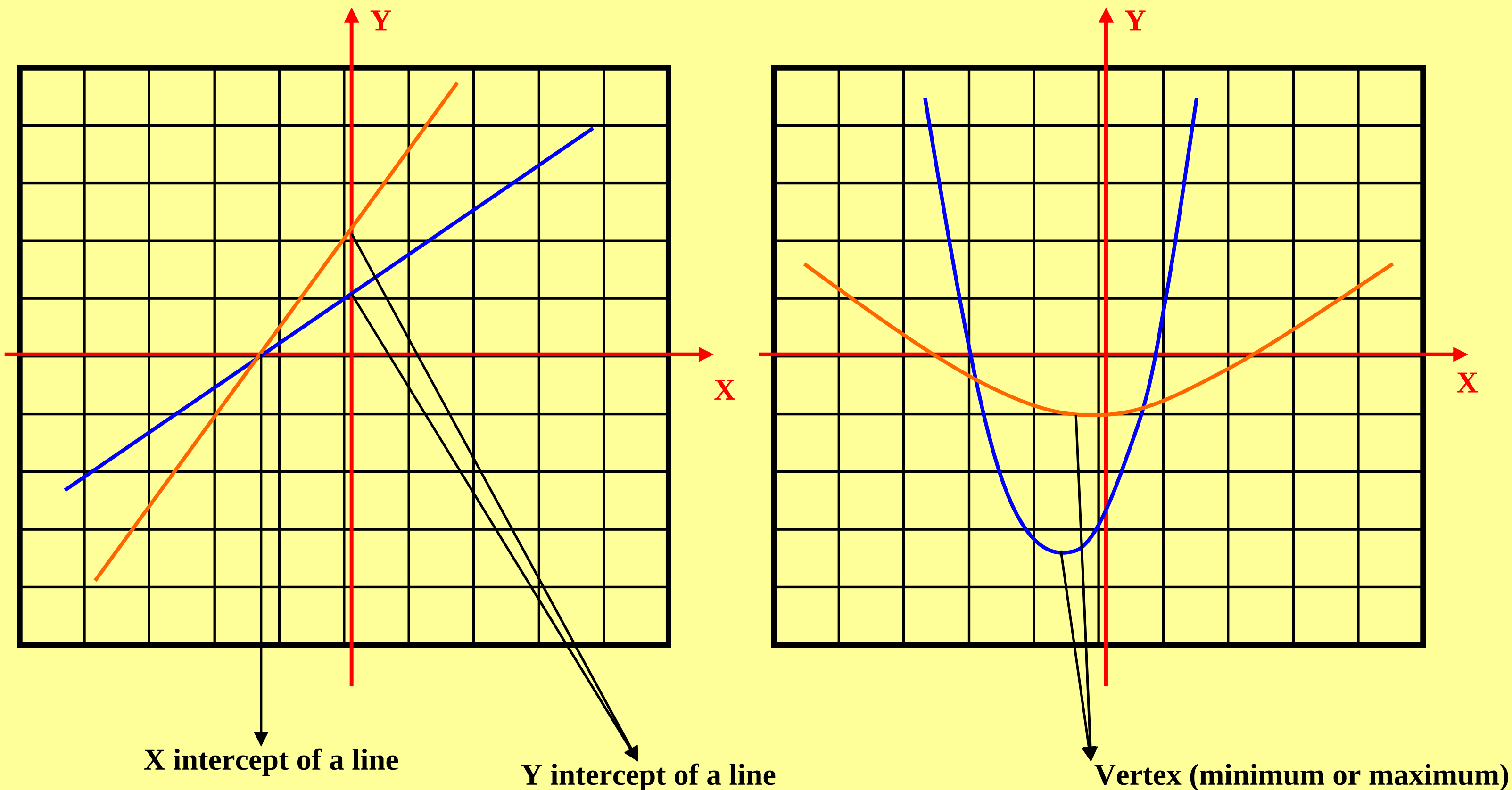
Continental United States Hurricane Strikes*
1950 - 2008
Saffir-Simpson Hurricane Categories (at Strike or Landfall)
Sustained Winds (MPH)
74-95 Category 1
96-110 Category 2
111-130 Category 3
131-155 Category 4
>155 Category 5
There were no hurricane strikes in the U.S. for the period 2000, 2001, 2006.
Due to density of storms in some locations, actual strike locations are approximate.
* STRIKES- includes hurricanes that did not make direct landfall, but did produce hurricane force winds over land.
Carol (1953)
Gerda (1969)
Edna (1954)
Carol (1954)
Donna (1960)
Gloria (1985)
Edna (1954)
Bob (1991)
Belle (1976)
Isabel (2003)
Connie (1955)
Ione (1955)
Ginger (1971)
Bertha (1996)
Fran (1996)
Diana (1984)
Charley (2004)
Gaston (2004)
Carol (1954)
Emily (1993)
Alex (2004)
Gloria (1985)
Barbara (1953)
Charley (1986)
Ophelia (2005)
Donna (1960)
Diane (1955)
Floyd (1999)
Bonnie (1998)
Hazel (1954)
Cindy (1959)
Hugo (1989)
Gracie (1959)
Able (1952)
Bob (1985)
David (1979)
Dora (1964)
Baker (1950)
Ivan (2004)
Erin (1995)
Opal (1995)
Dennis (2005)
Eloise (1975)
Flossy (1956)
Florence (1953)
Agnes (1972)
Earl (1998)
Alma (1966)
Kate (1985)
Danny (1997)
Frederic (1979)
Georges (1998)
Ethel (1960)
Elena (1985)
Katrina (2005)
Camille (1969)
Flossy (1956)
Danny (1997)
Cindy (2005)
Florence (1988)
Gustav (2008)
Betsy (1965)
Bob(1979)
Carmen (1974)
Juan (1985)
Babe (1977)
Easy (1950)
Gladys (1968)
Charley (2004)
Donna (1960)
Isbell (1964)
Wilma (2005)
Georges (1998)
Irene (1999)
David (1979)
Erin (1995)
Jeanne (2004)
Frances (2004)
Cleo (1964)
Katrina (2005)
King (1950)
Andrew (1992)
Betsy (1965)
Inez (1966)
Donna (1960)
Floyd (1987)
Danny (1985)
Edith (1971)
Audrey (1957)
Rita (2005)
Bonnie (1986)
Humberto (2007)
Cindy (1963)
Chantal (1989)
Debra (1959)
Jerry (1989)
Alicia (1983)
Fern (1971)
Carla (1961)
Ike (2008)
Lili (2002)
Hilda (1964)
Andrew (1992)
Claudette (2003)
Celia (1970)
Bret (1999)
Dolly (2008)
Allen (1980)
Beulah (1967)
NOAA's National Climatic Data Center ■ Asheville, North Carolina
Protecting the past ... Revealing the future



Total number of hurricane strikes by counties/parishes, 1900-2007

Data from NWS NHC 46: Hurricane Experience Levels of Coastal County Populations from Texas to Maine. Jerry D. Jarrell, Paul J. Hebert, and Max Mayfield. August, 1992, with updates.

Graphical Representation in a plane



$Y = m X + b$ Equation of a line in the slope-intercept form

m – slope or rate of change, $m > 0$ line goes up, $m < 0$ goes down

b – y intercept of a line

Larger the value of "m" closer to the y-axis a line is located

Y = m X is called a linear variation or proportion

Y = m / X is called an inverse variation or inversely proportional

$Y = a X^2 + b X + c$ Equation of a parabola

$X_v = - b/2a$ coordinate of the vertex

If $a > 0$ it opens up, $a < 0$ it opens down

Larger the value of "a" narrower a parabola looks like

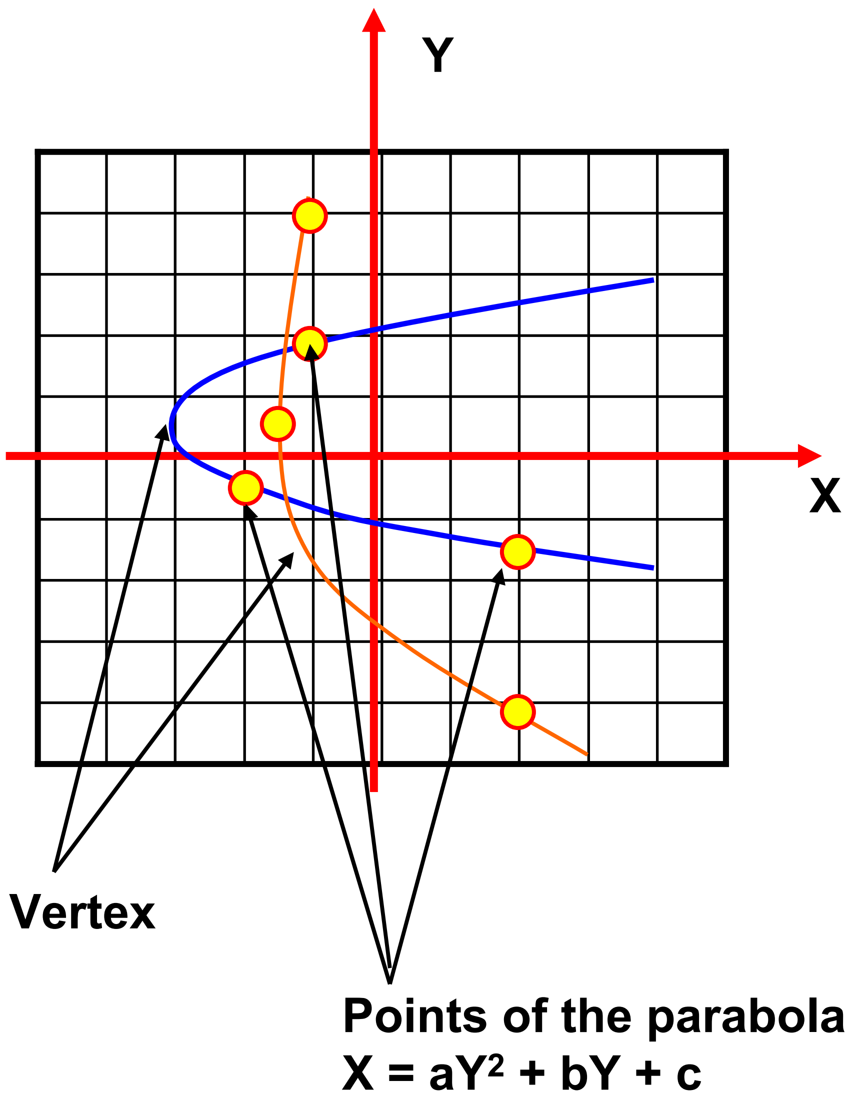
$$m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{rise}{run}$$

What do variables X and Y have in common with the real world?

Cause and Effect Principle

X plays the role of cause or control parameter

Y plays the role of effect or result obtained by changing the control parameter



1. Substitute (X,Y) into the equation of the Parabola.

2. Set the system of linear equations:

$$X_1 = a(Y_1)^2 + bY_1 + c$$
$$X_2 = a(Y_2)^2 + bY_2 + c$$
$$X_3 = a(Y_3)^2 + bY_3 + c$$

3. Solve the system in order to obtain the coefficients a, b, and c.

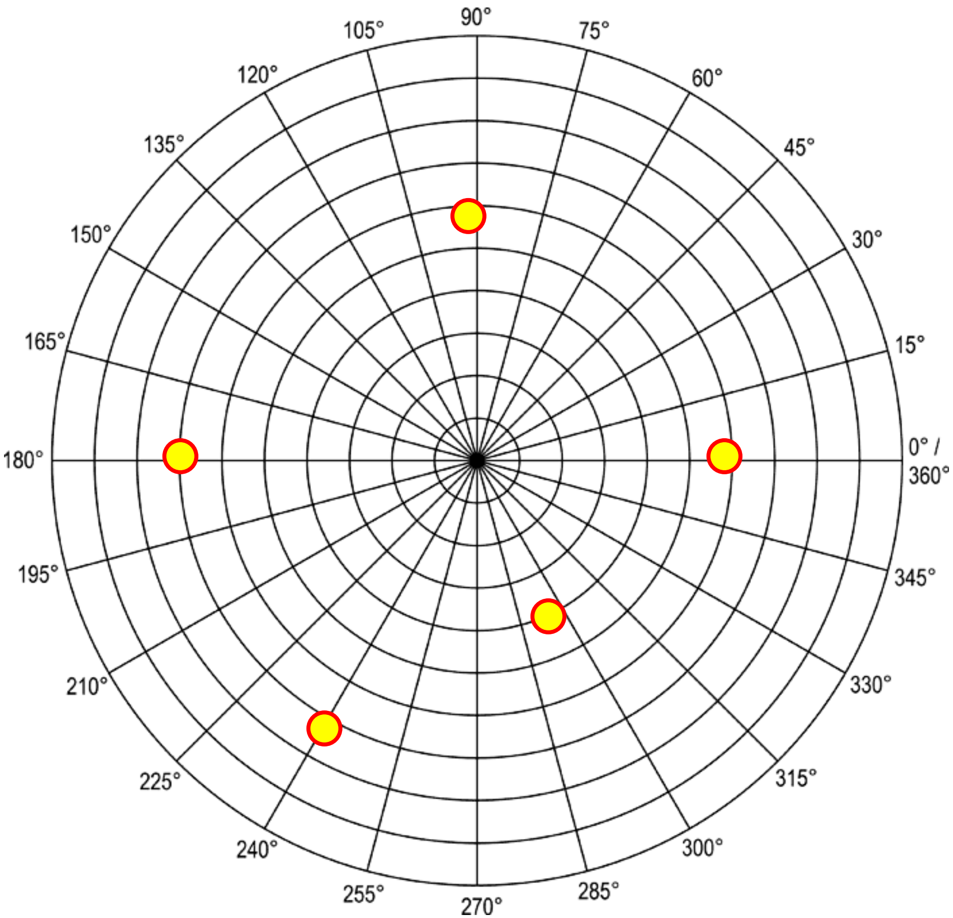
$$A = Det\begin{pmatrix} (Y_1)^2 & Y_1 & 1 \\ (Y_2)^2 & Y_2 & 1 \\ (Y_3)^2 & Y_3 & 1 \end{pmatrix}$$

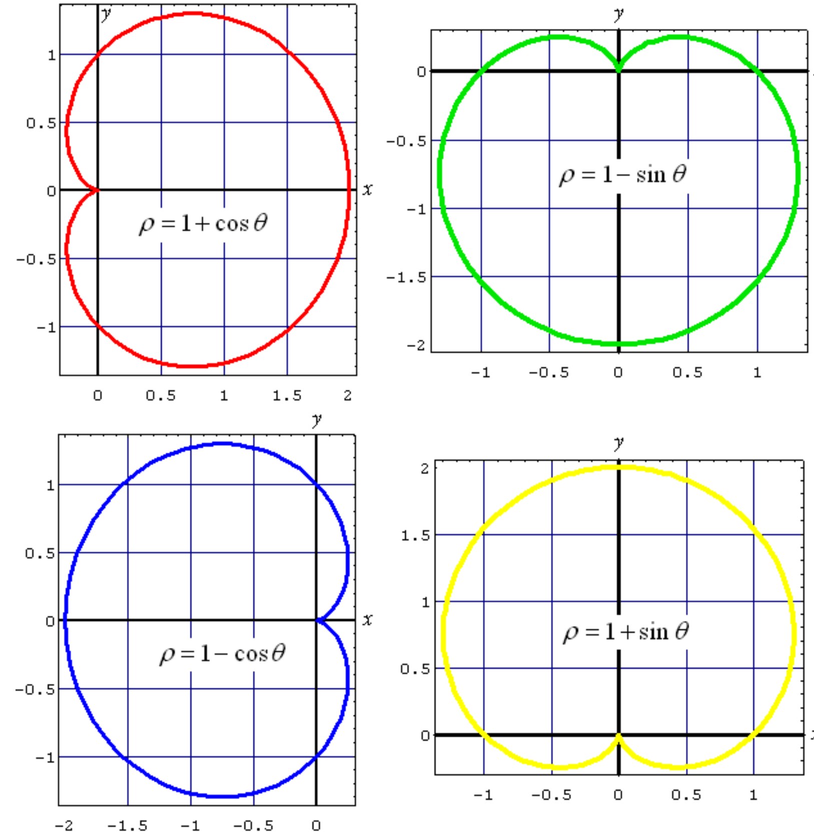
$$A_1 = Det\begin{pmatrix} X_1 & Y_1 & 1 \\ X_2 & Y_2 & 1 \\ X_3 & Y_3 & 1 \end{pmatrix} \qquad a = \frac{A_1}{A}$$

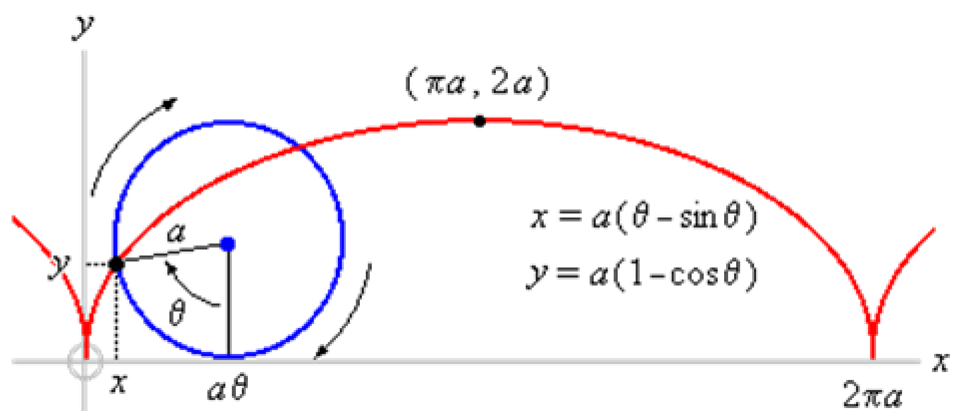
4. Once coefficients are obtained, then find the vertex according to:

$$Y_V = \frac{b^2}{2a} \qquad X_V = a(Y_V)^2 + bY_V + c$$

Polar Coordinates and Planar Curves

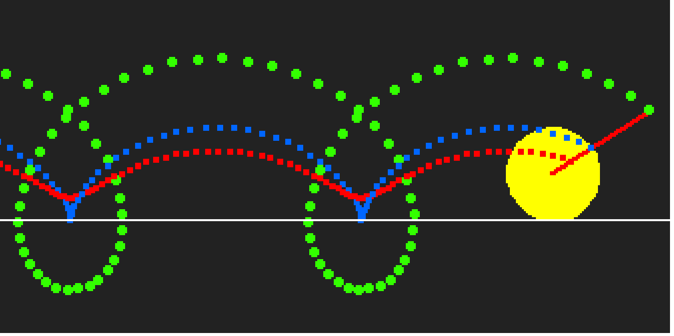




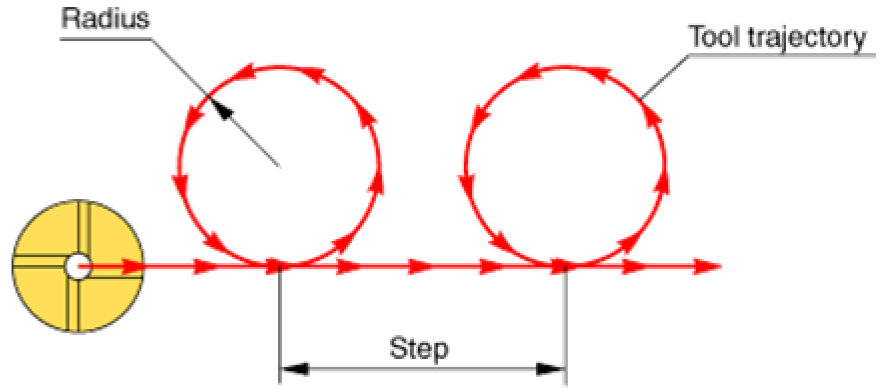


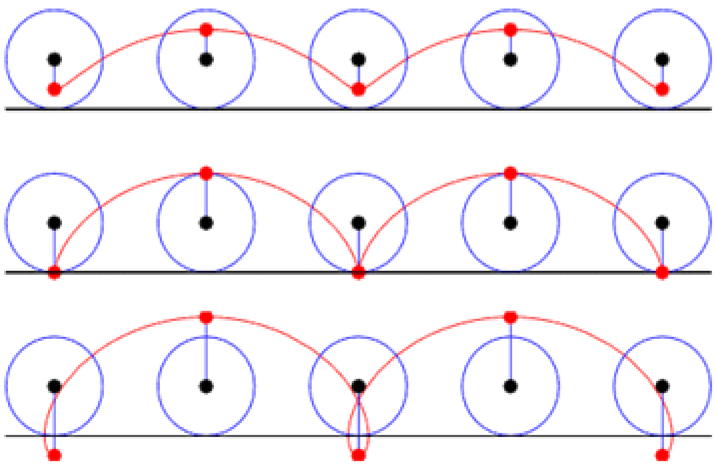
X = r(θ) cos(θ)
Y = r(θ) sin(θ)
(x,y) rectangular coordinates

Hurricanes move following a trochoidal curve

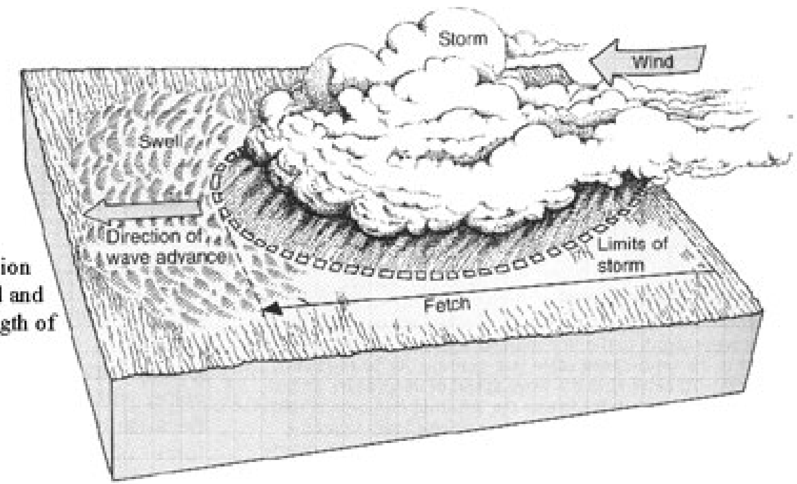


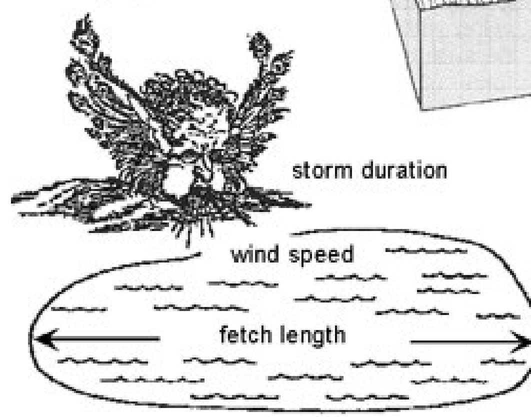
$$\begin{cases} x = a\phi - b \sin \phi \\ y = a - b \cos \phi \end{cases}$$

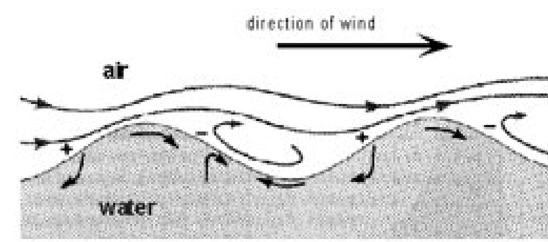




Waves are formed in a generating area where the wind begins to disturb the water surface, forming ripples and then waves. The size of waves generated is a function of wind speed, duration of coupling between the wind and the water surface, and the length of this coupling.

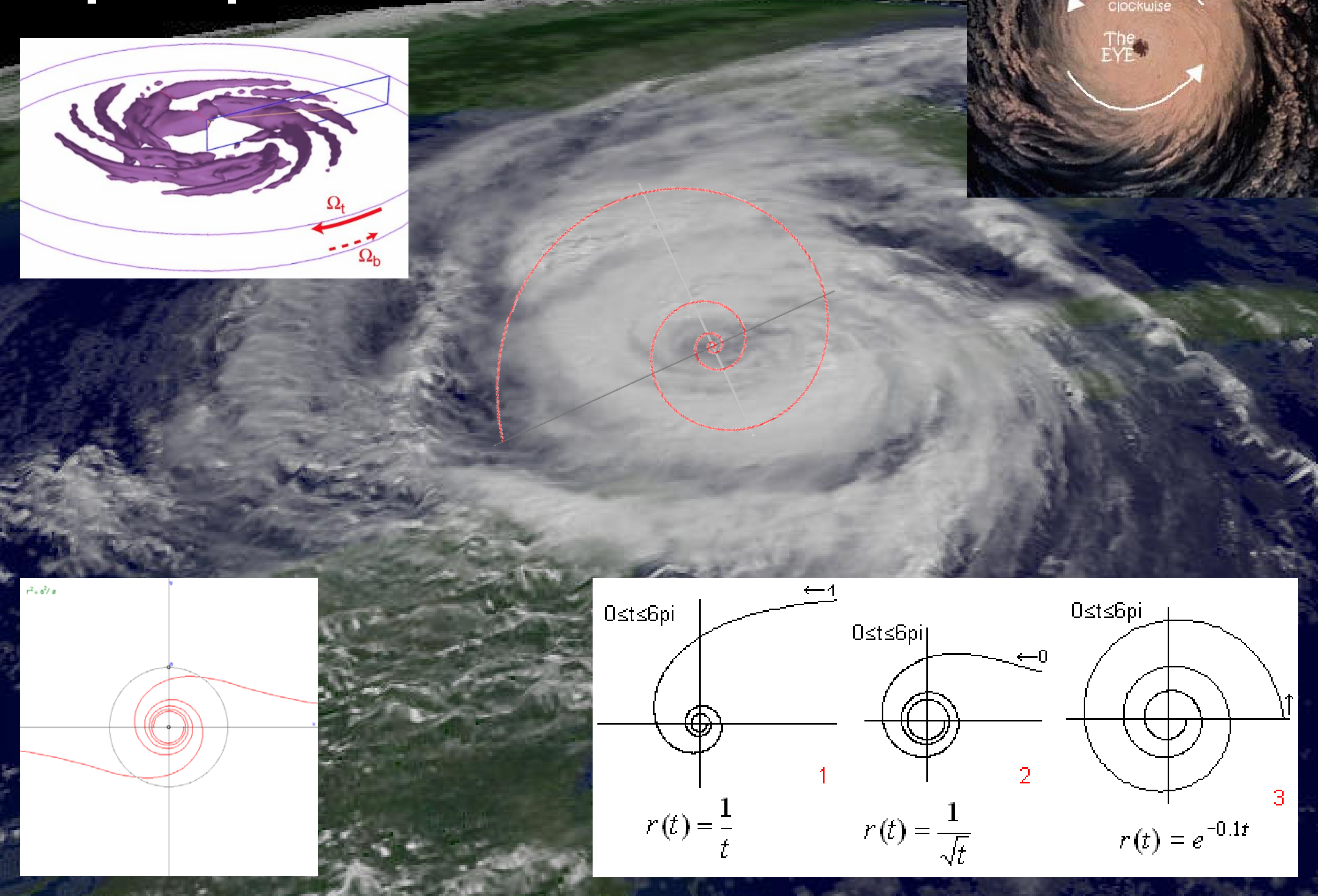




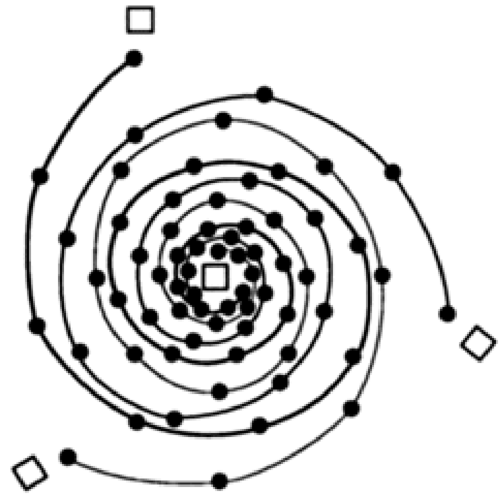


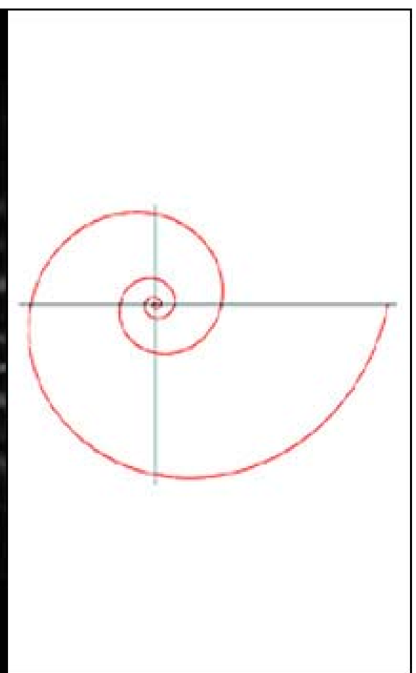
waves are formed by frictional drag of the wind across the water surface. Growth of the wave is from the sheltering effect of the wave crest.

Spiral patterns in hurricanes



Logarithmic Spirals – The preferred spirals of Nature





ST.THOMAS UNIVERSITY
School of SCIENCE, TECHNOLOGY & ENGINEERING MANAGEMENT

BS in Mathematics

PREREQUISITE REQUIRED COURSES: 19 credits

MAT 205 Applied Statistics (3 credits)
MAT 232 Calculus I (4 credits)
MAT 233 Calculus II (4 credits)
CHE 101/L General Chemistry I + Laboratory (4 credits)
CHE 102/L General Chemistry II + Laboratory (4 credits)

MAJOR REQUIREMENTS: 35 credits total

Core Mathematics Courses: (13 credits)

MAT 234 Calculus III (4 credits)
MAT 306 Differential Equations (3 credits)
MAT 311 Linear Algebra (3 credits)
MAT 316 Complex Variables (3 credits)

Mathematics Electives: (6 credits)

Take two mathematics courses at the 300 or 400 level.

Computing Requirement: (6 credits)

Take two courses.
CIS 230 Introduction to Java Programming (3 credits)
CIS 235 Introduction to C++ Programming (3 credits)
CIS 302 Advanced C++ Programming (3 credits)
CIS 310 Advanced Java Programming (3 credits)
CIS 360 Data Structures (3 credits)
CIS 351 Systems Analysis and Design (3 credits)
CIS 430 Database Management Systems (3 credits)

Physical Science Requirements: (10 credits)

PHY 207/L University Physics I + Laboratory (5 credits)
PHY 208/L University Physics II + Laboratory (5 credits)
Sub-Total Credits: 54

GENERAL EDUCATION REQUIREMENTS: 42 credits

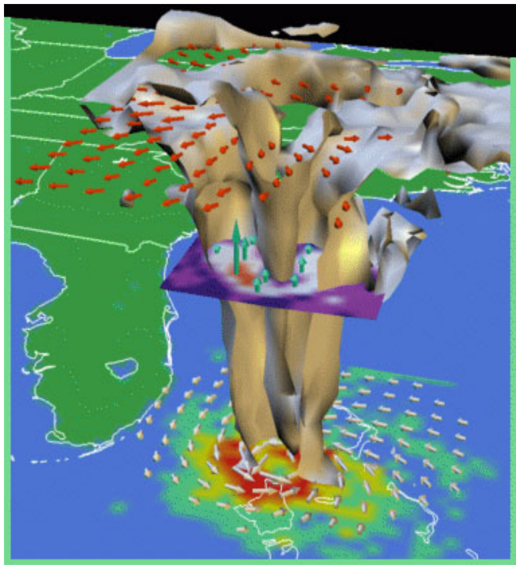
(Program requirements will satisfy 9 credits of the GER.)

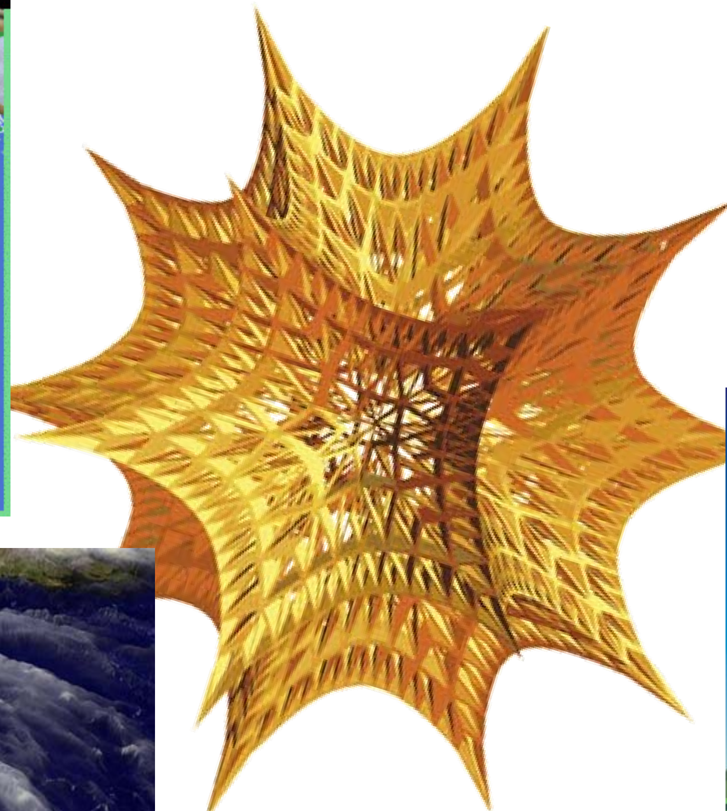
GENERAL ELECTIVES: 24 credits

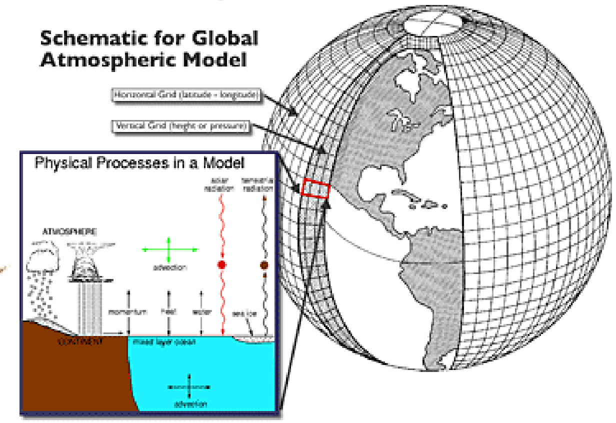
Total credits: 120

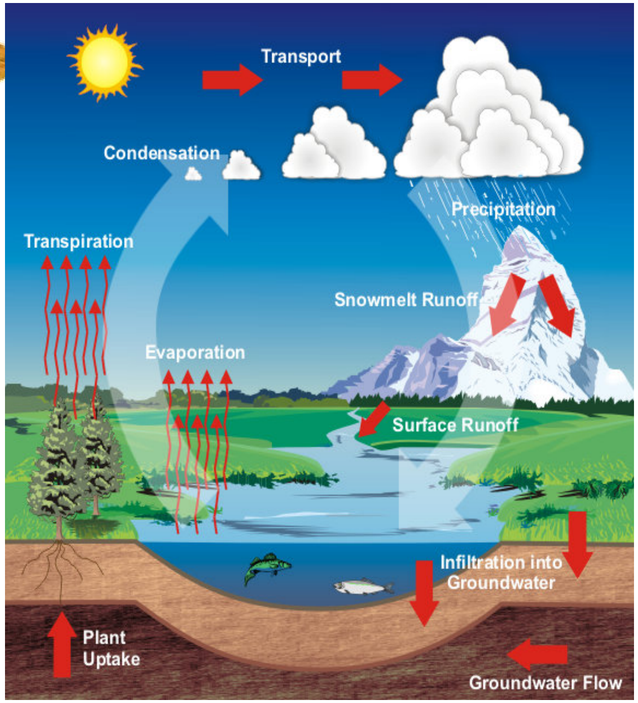
Mathematics and Atmospheric Sciences

Ongoing research project # 1: The effect of Climate and Weather Variability on Hurricane Dynamics









Ongoing research project # 2: Asthma – Weather connection

Air Quality and Respiratory disorders: Modeling asthma attacks considering the environmental triggers, the mechanics of lung functioning, immune response and genetic factors.

Asthma Statistics Worldwide: A brief overview

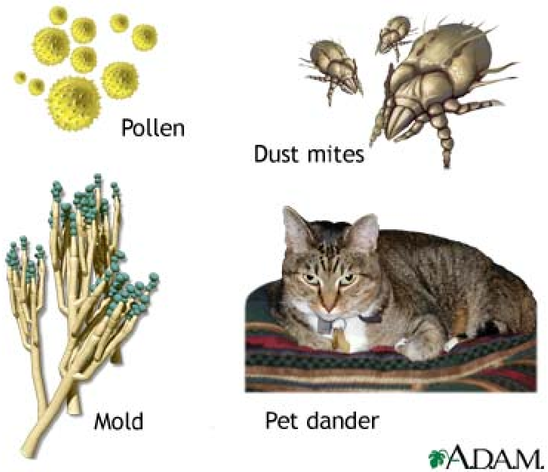
# of people diagnosed: more than 150 M
Europe: the # of cases has doubled
USA: the # of cases has increased more than 60%
India: between 15 and 20 M
Africa: between 11 and 18% population
# of deaths yearly: around 180,000
Miami Dade County – 7.1% Middle and HS ch
were reported with a

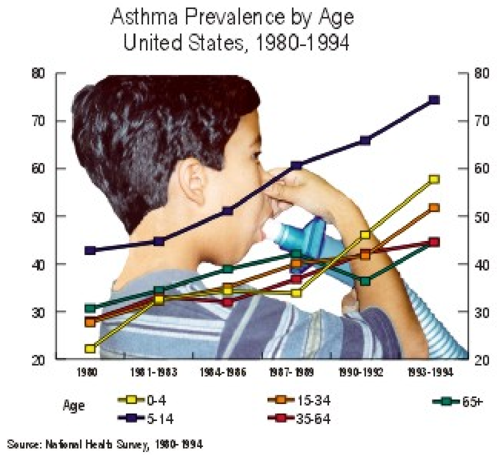
The # of hospitalizations due to asthma has doubled.
The # 1 cause of school absences and 35 % of parents missed work

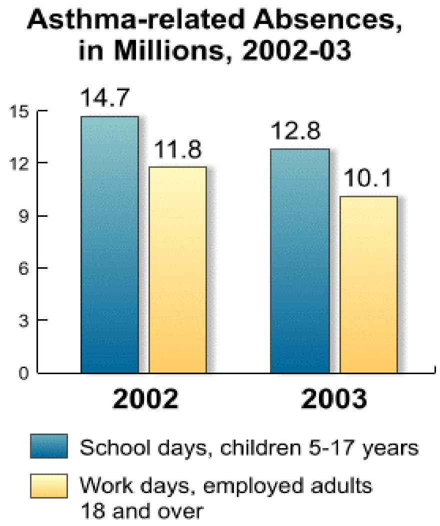
Urban Heat Island Effect

Man is likely playing a role in climate change through urbanization and land use changes competing with greenhouse Gases and cycles of Nature

- In cities, vertical walls, steel and concrete absorb the sun's heat and are slow to cool at night
- Nights may be 10 or more degrees warmer in and near cities than in rural areas some nights
- Temperatures measured in cities increase as they grow.







ST.THOMAS UNIVERSITY
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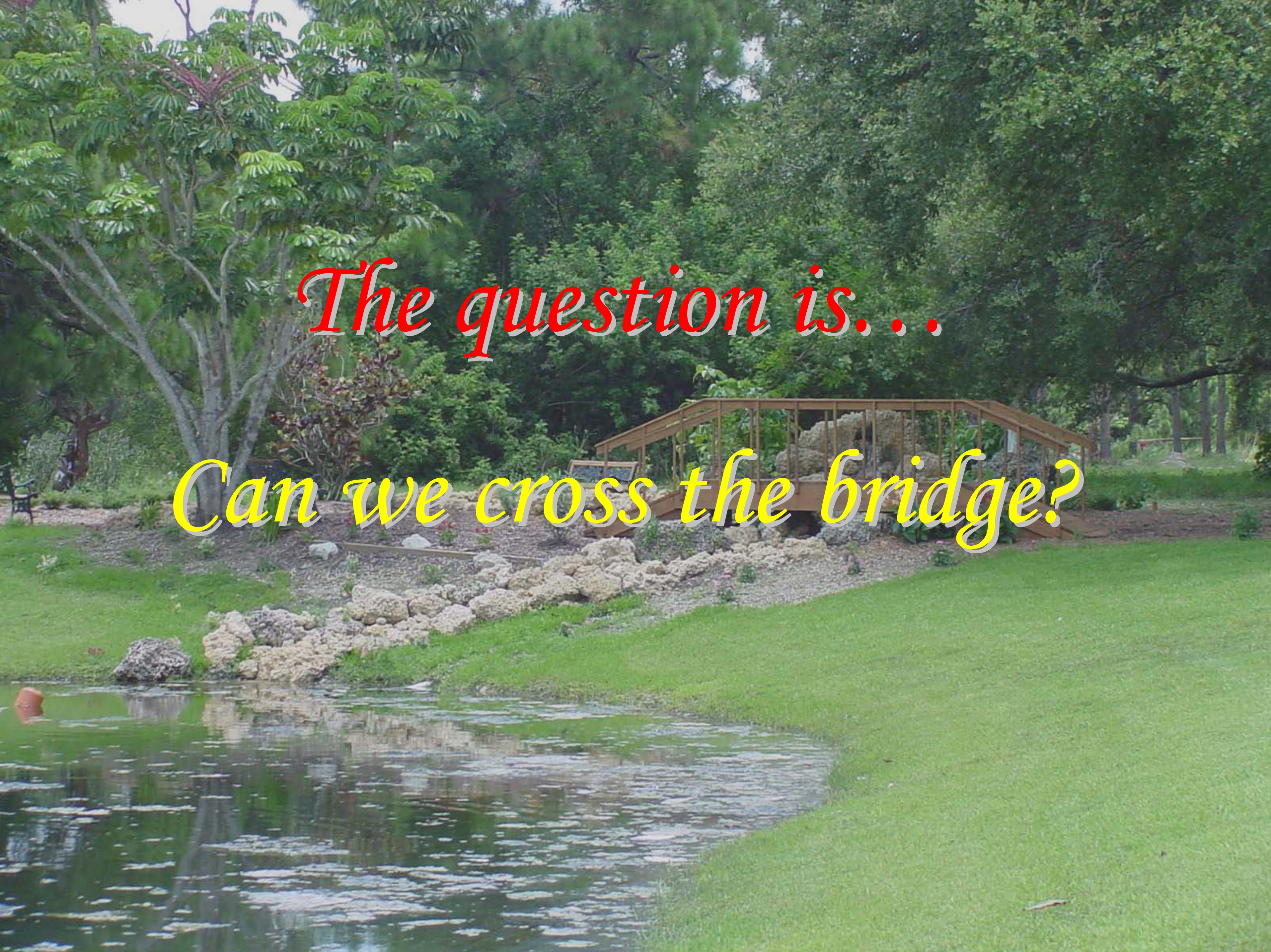
Leaders Make the Discoveries That Build Our Future

Miami Dade College

Science & Mathematics Fellows Program

- **Start Date: August 2008 - 30 freshmen & 30 juniors who transfer with an AA.**
- **Qualified students may receive financial aid and academic scholarships.**
- **Research based in state of the art Science & Technology facility.**


The question is…
Can we cross the bridge?