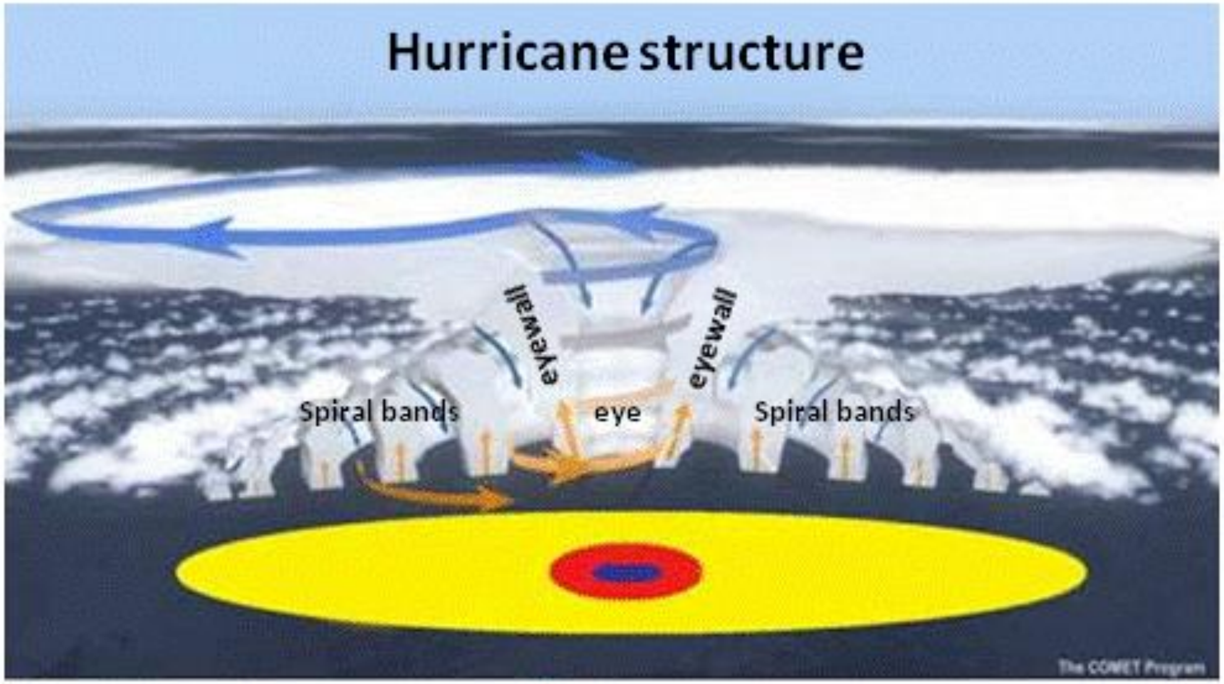
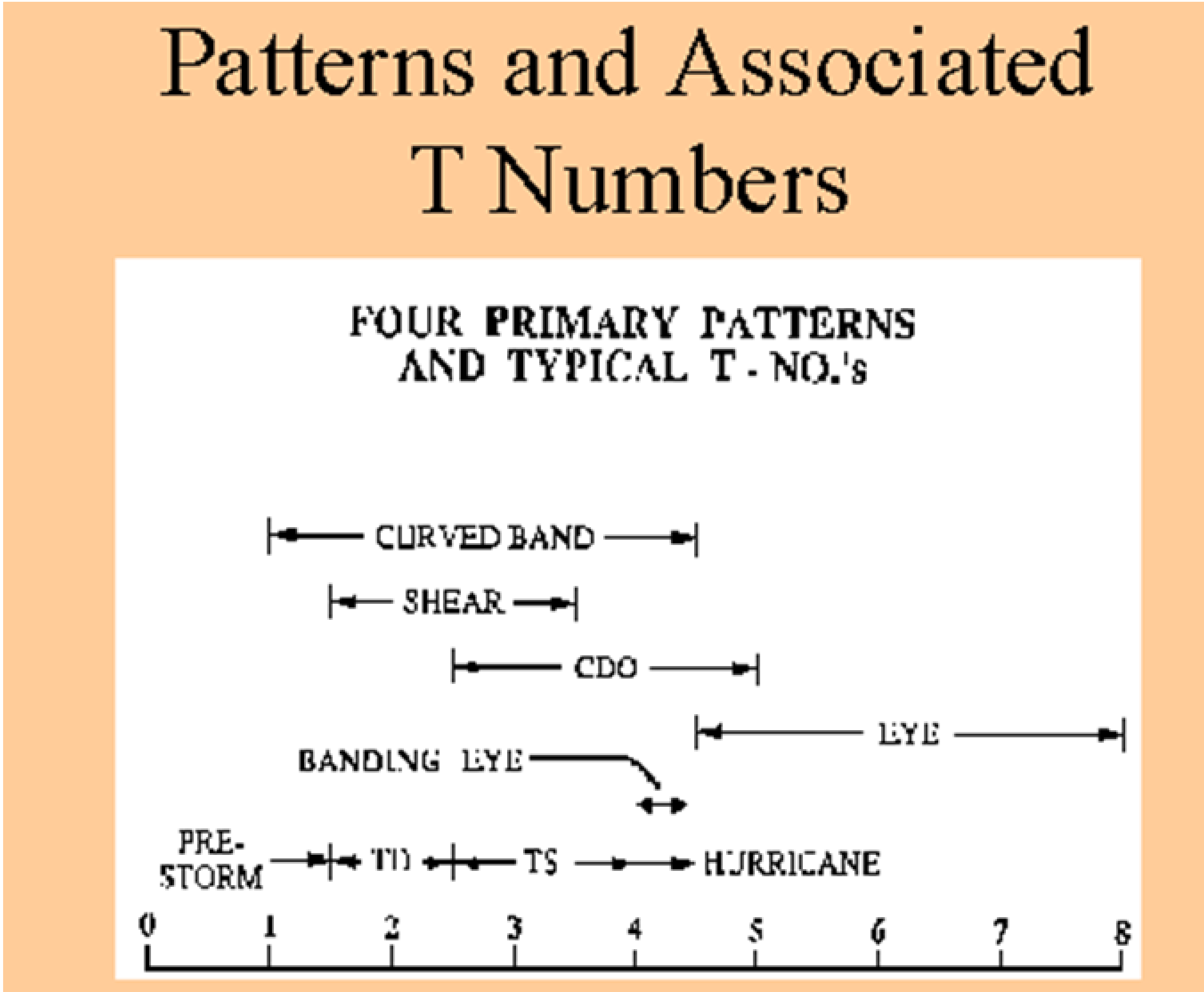


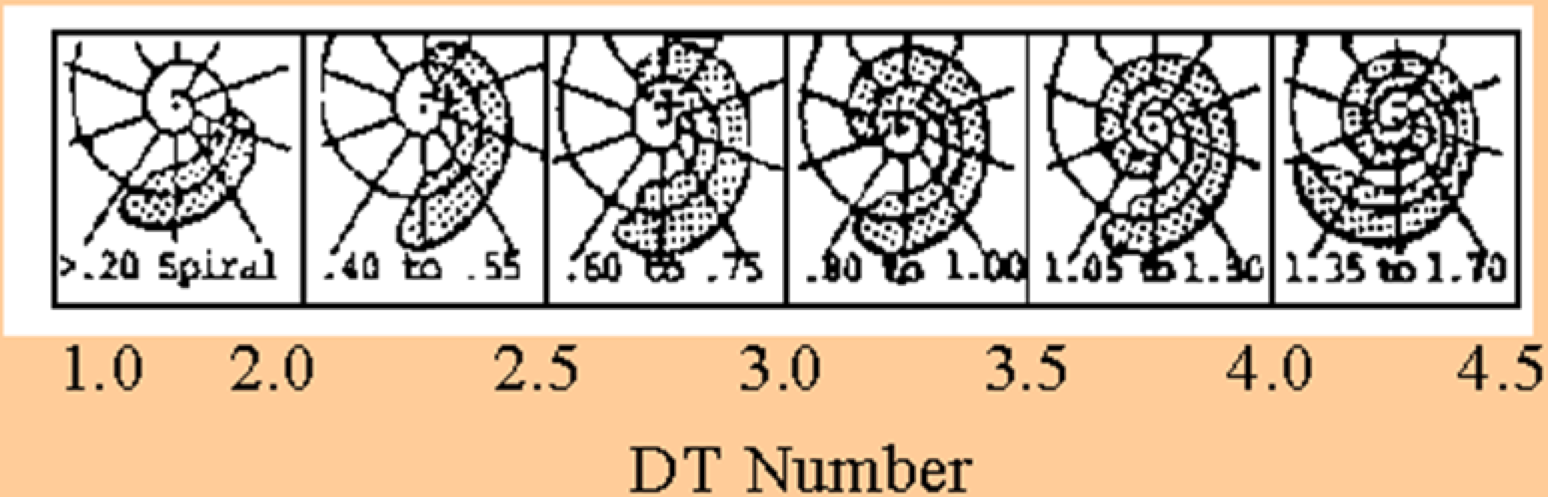
Light Winds — *Very Strong Winds*

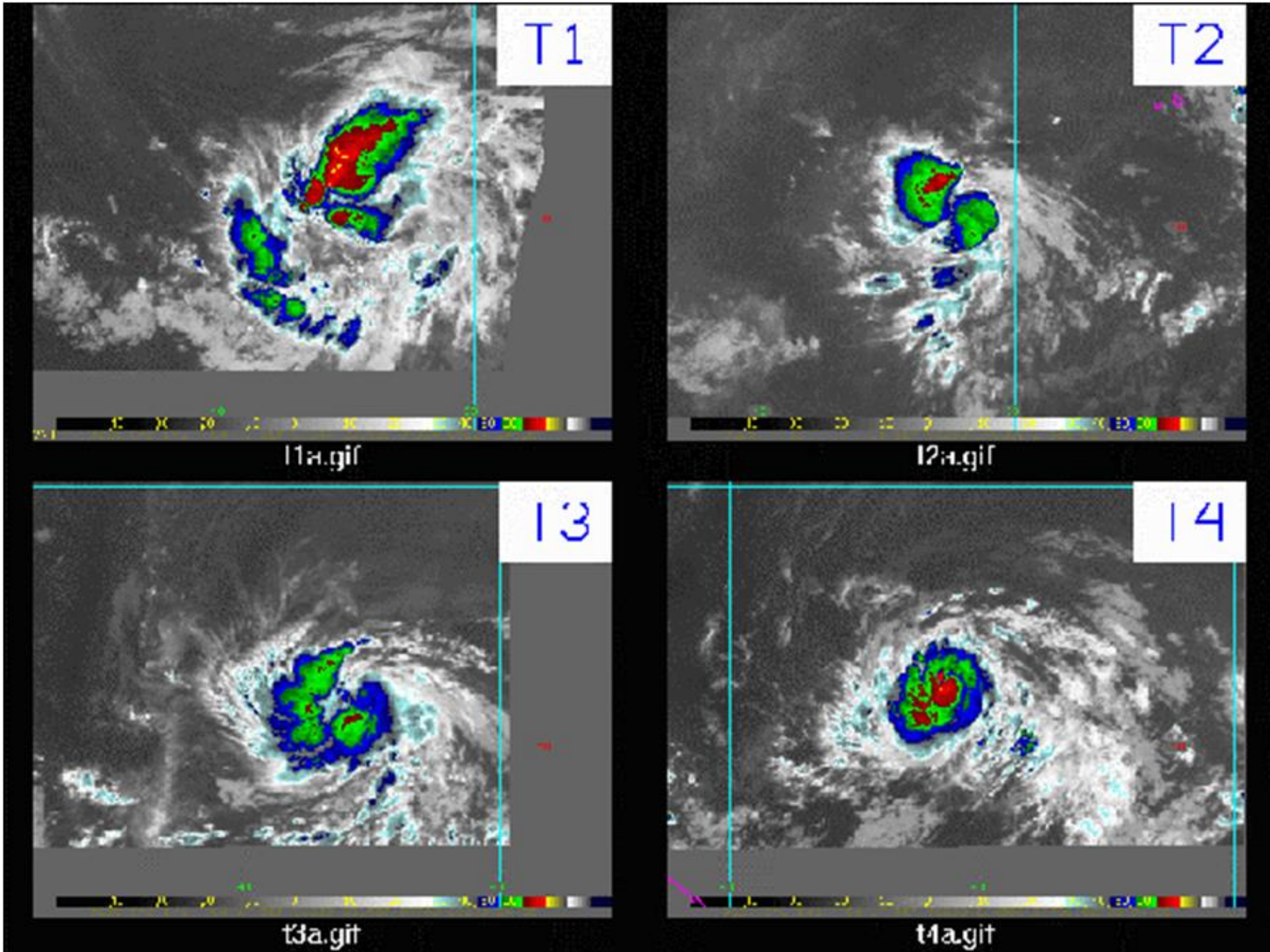
Transition from very strong winds to light winds at the outer edge

Hurricanes follow a general pattern from formation to maturity.
Pattern is so consistent forecasters use the Dvorak technique to estimate intensity



Curved Band Pattern Cont'd

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T2
T3
T4
t1a.gif
t2a.gif
t3a.gif
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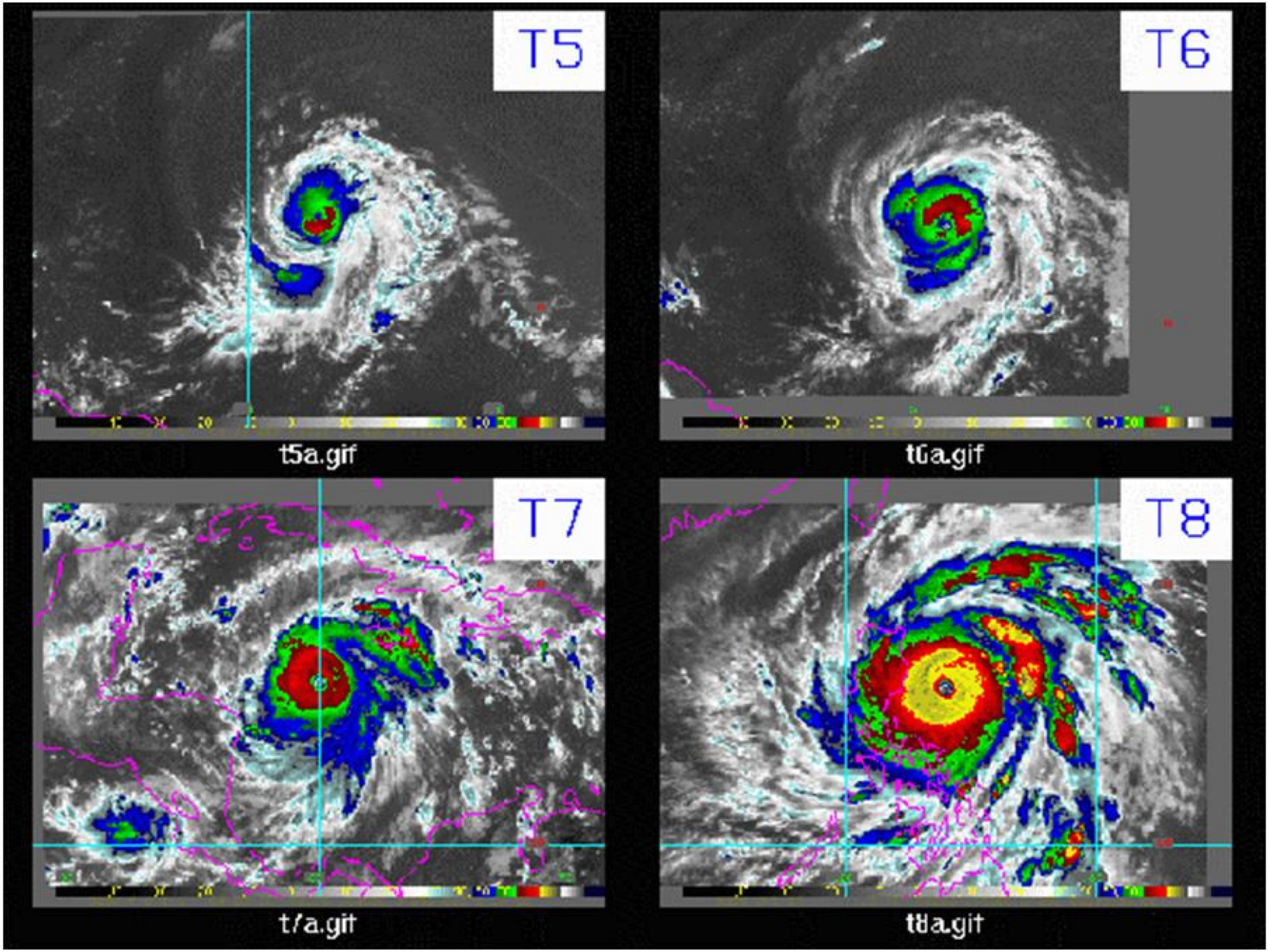
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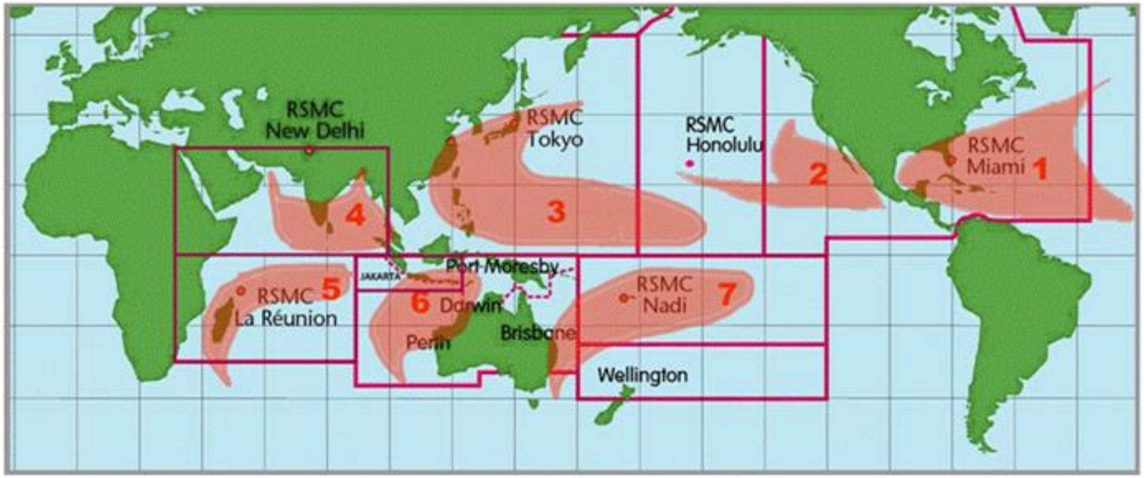


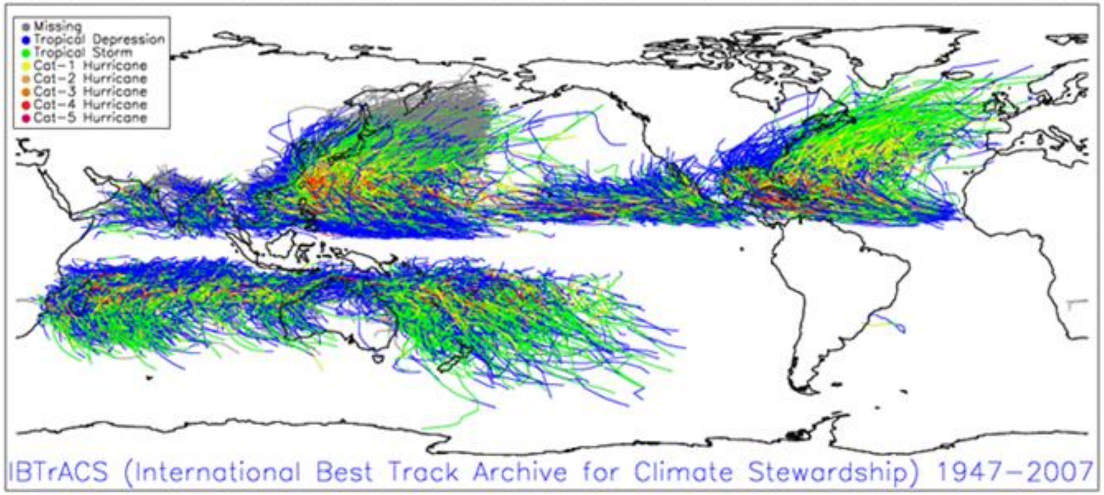
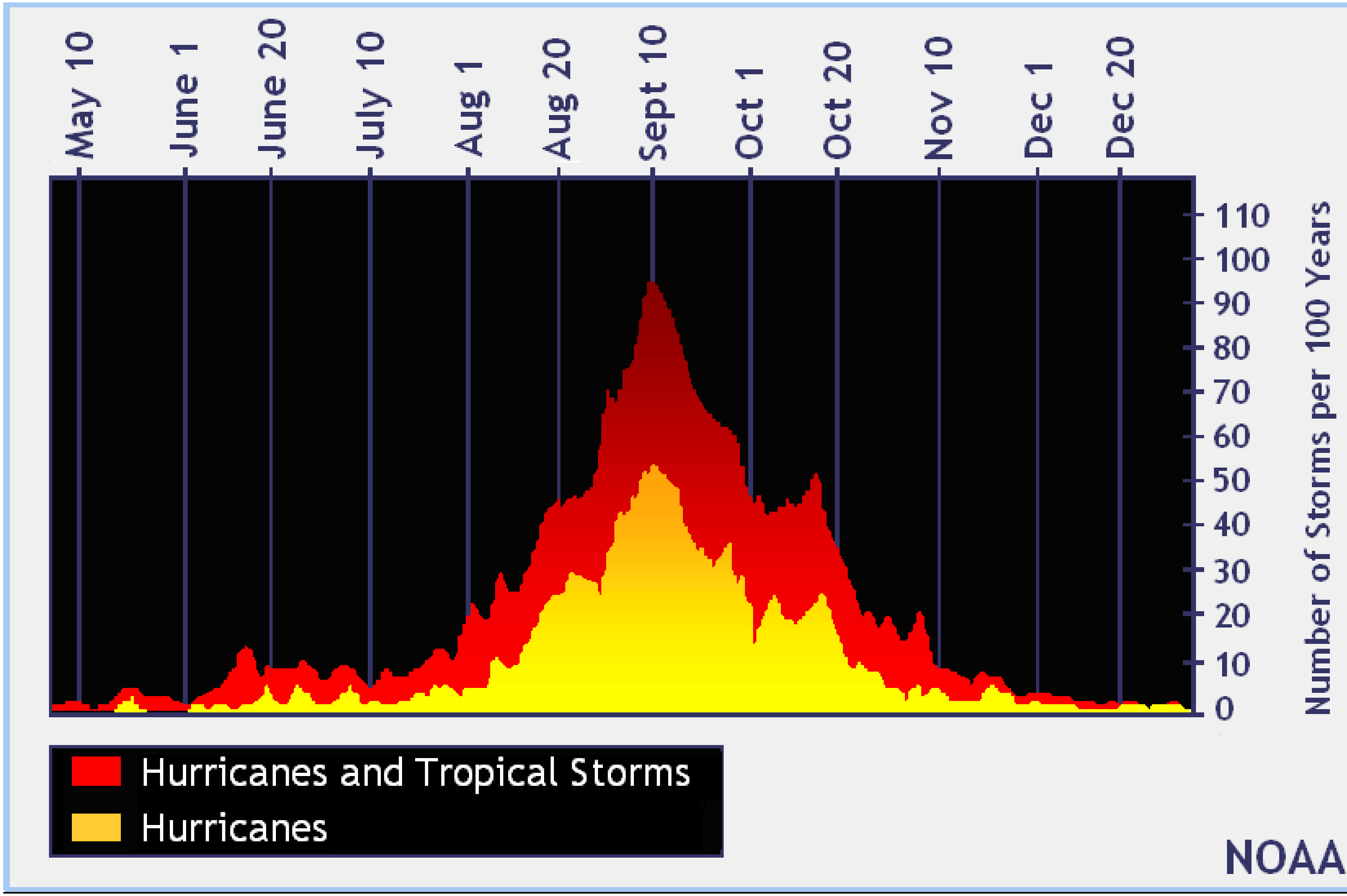
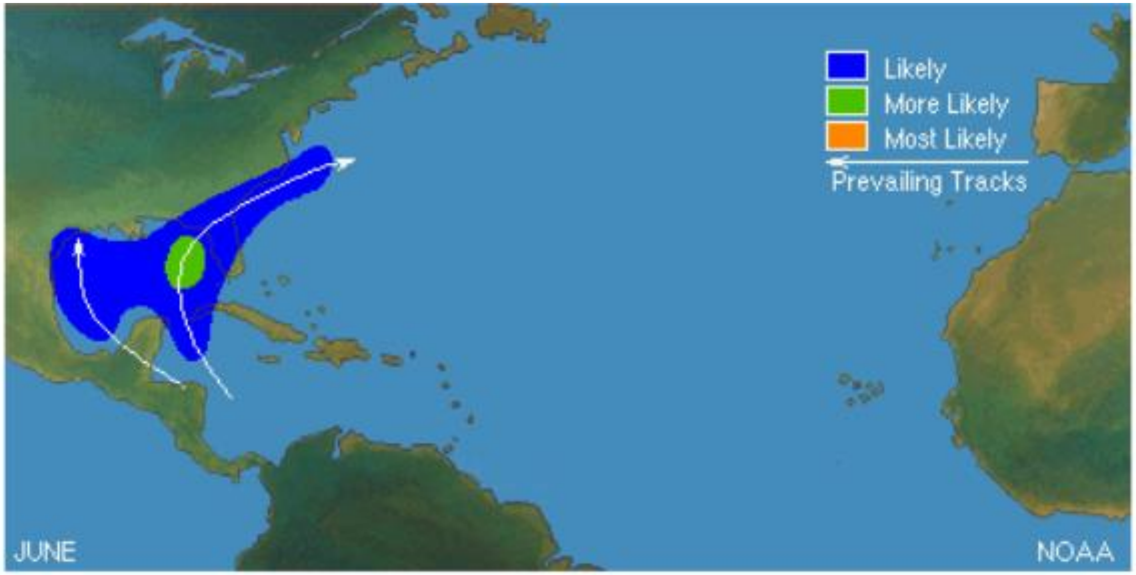


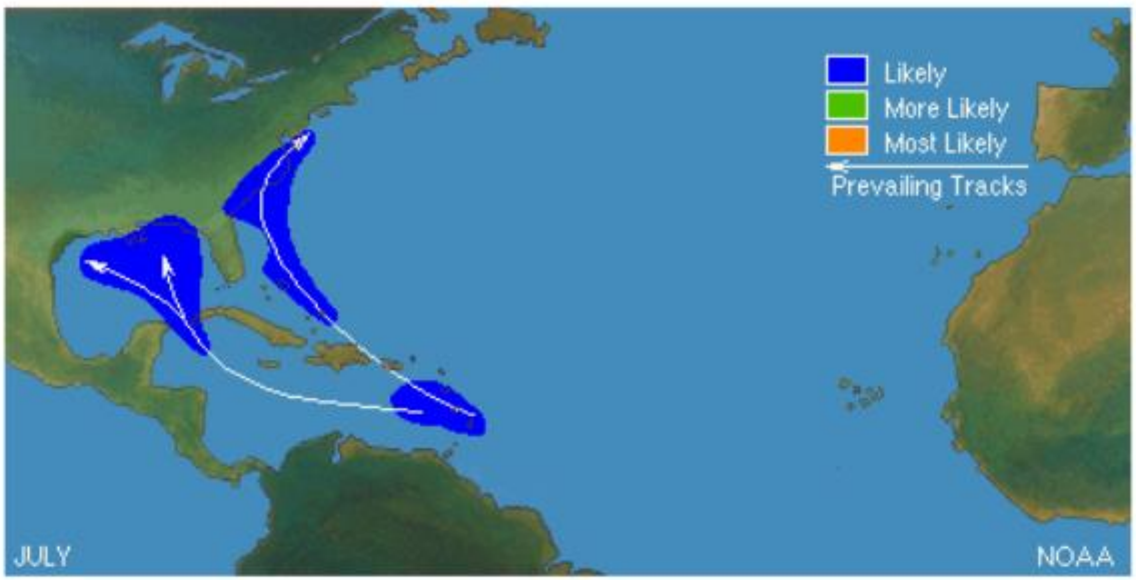
Figure 3. (Top) Global genesis regions (in red), the Regional Specialized Meteorological Centers (RSMCs), and Tropical Cyclone Warning Centers (TCWCs; Wellington, Brisbane, Perth, Darwin, Port Moresby, and Jakarta). For example, the National Weather Service National Hurricane Center and the Japan Meteorological Agency Typhoon Center are RSMCs. (Bottom) Global tropical depression, tropical storm, and hurricane tracks by U.S. Saffir-Simpson categories for 1947-2007. "Missing" indicates a position was available but intensity data was missing. Top figure from (4). Bottom figure courtesy of Ken Knapp, and adopted from (5).



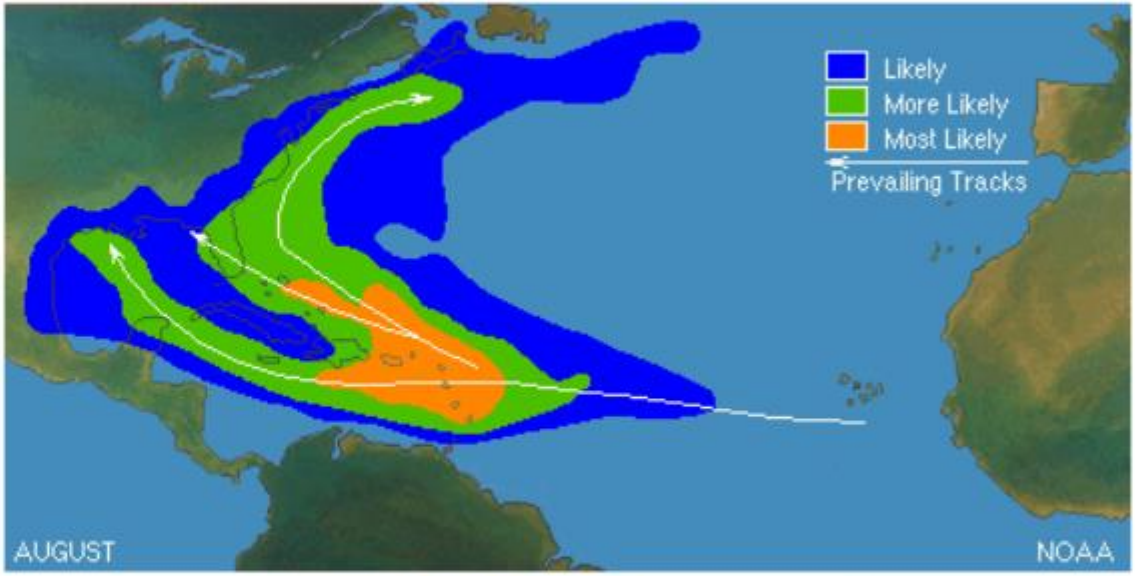
May 10
June 1
June 20
July 10
Aug 1
Aug 20
Sept 10
Oct 1
Oct 20
Nov 10
Dec 1
Dec 20
110
100
90
80
70
60
50
40
30
20
10
0
Number of Storms per 100 Years
Hurricanes and Tropical Storms
Hurricanes
NOAA

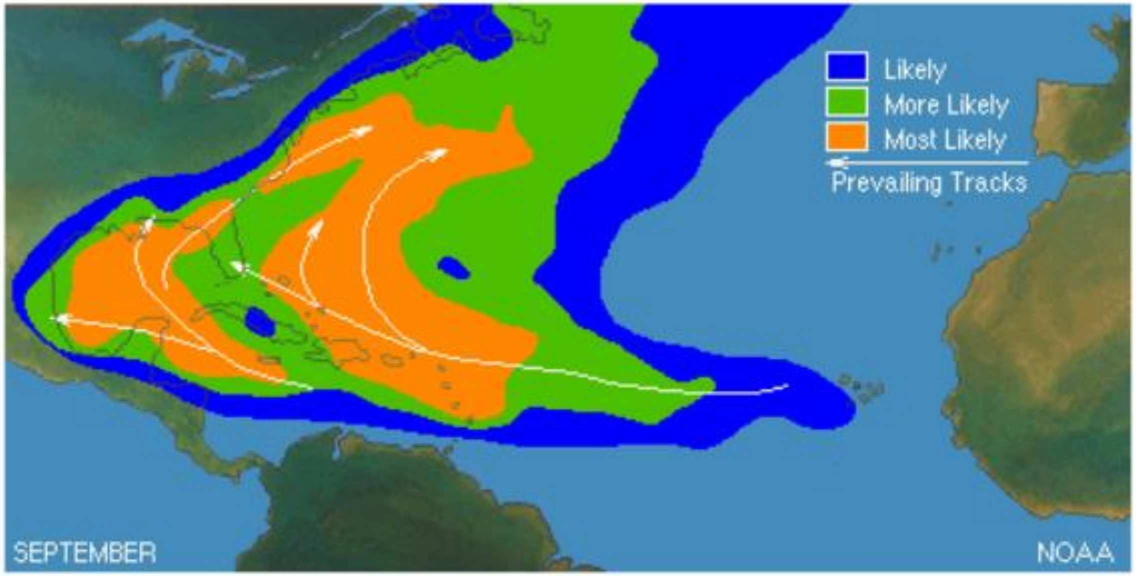
Climatological Areas of Origin and Typical Hurricane Tracks by Month



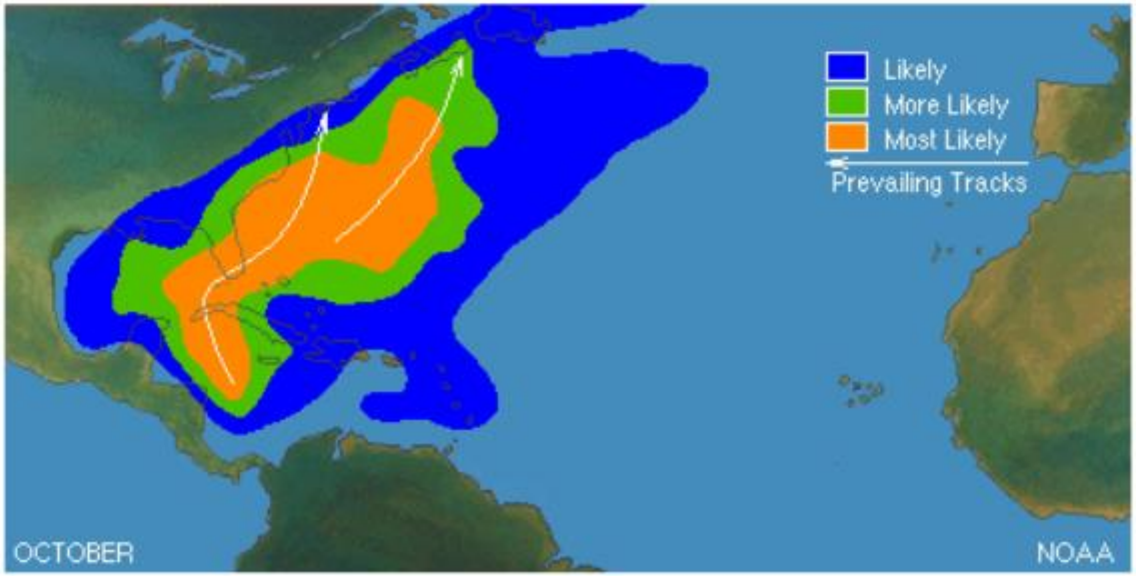


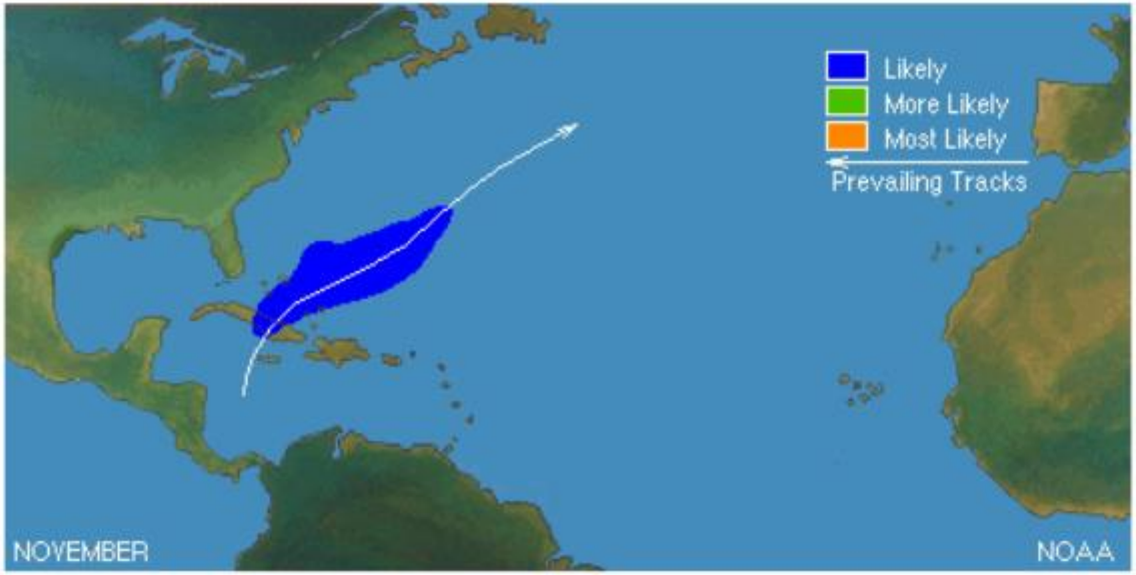
Climatological Areas of Origin and Typical Hurricane Tracks by Month





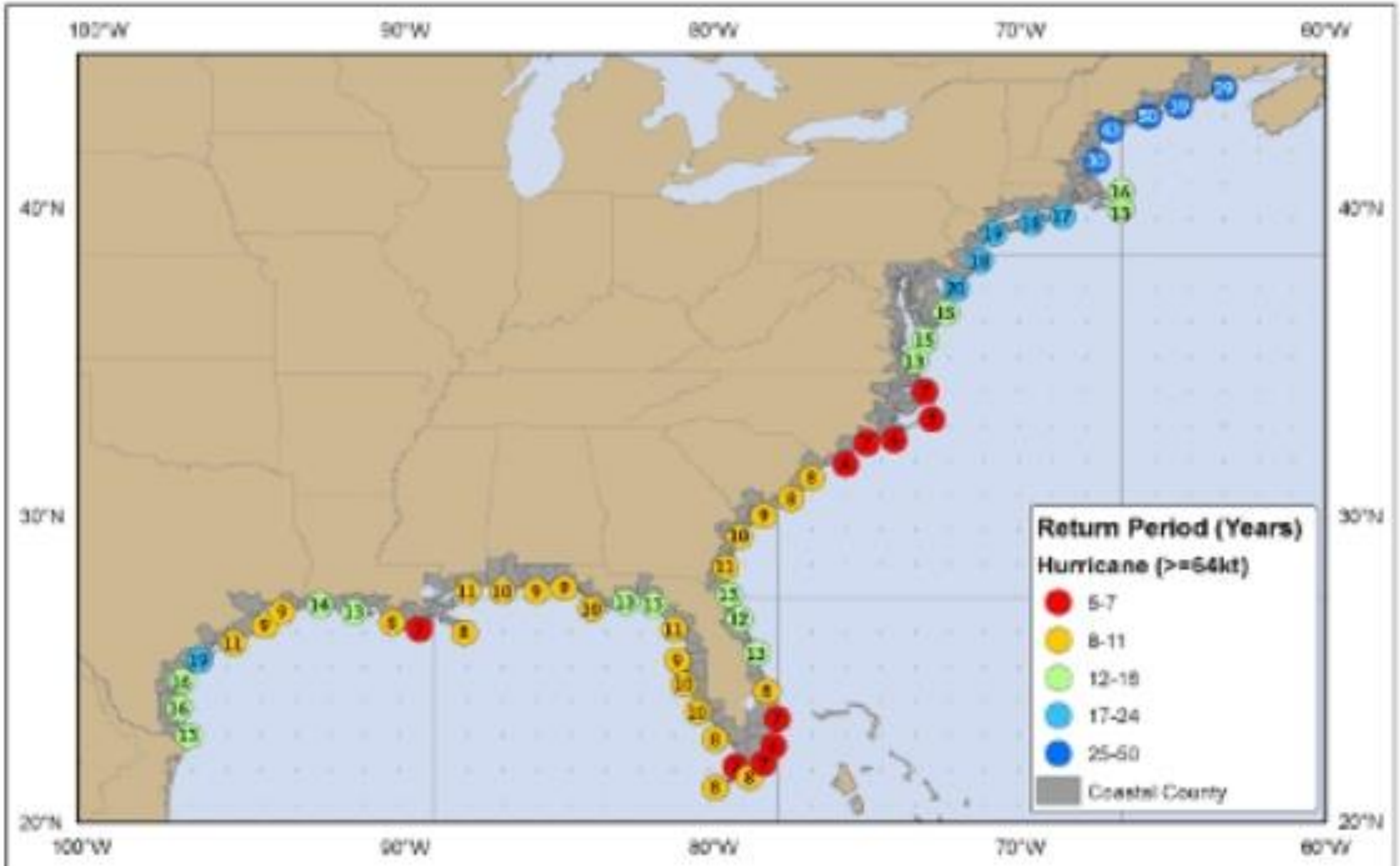
Climatological Areas of Origin and Typical Hurricane Tracks by Month



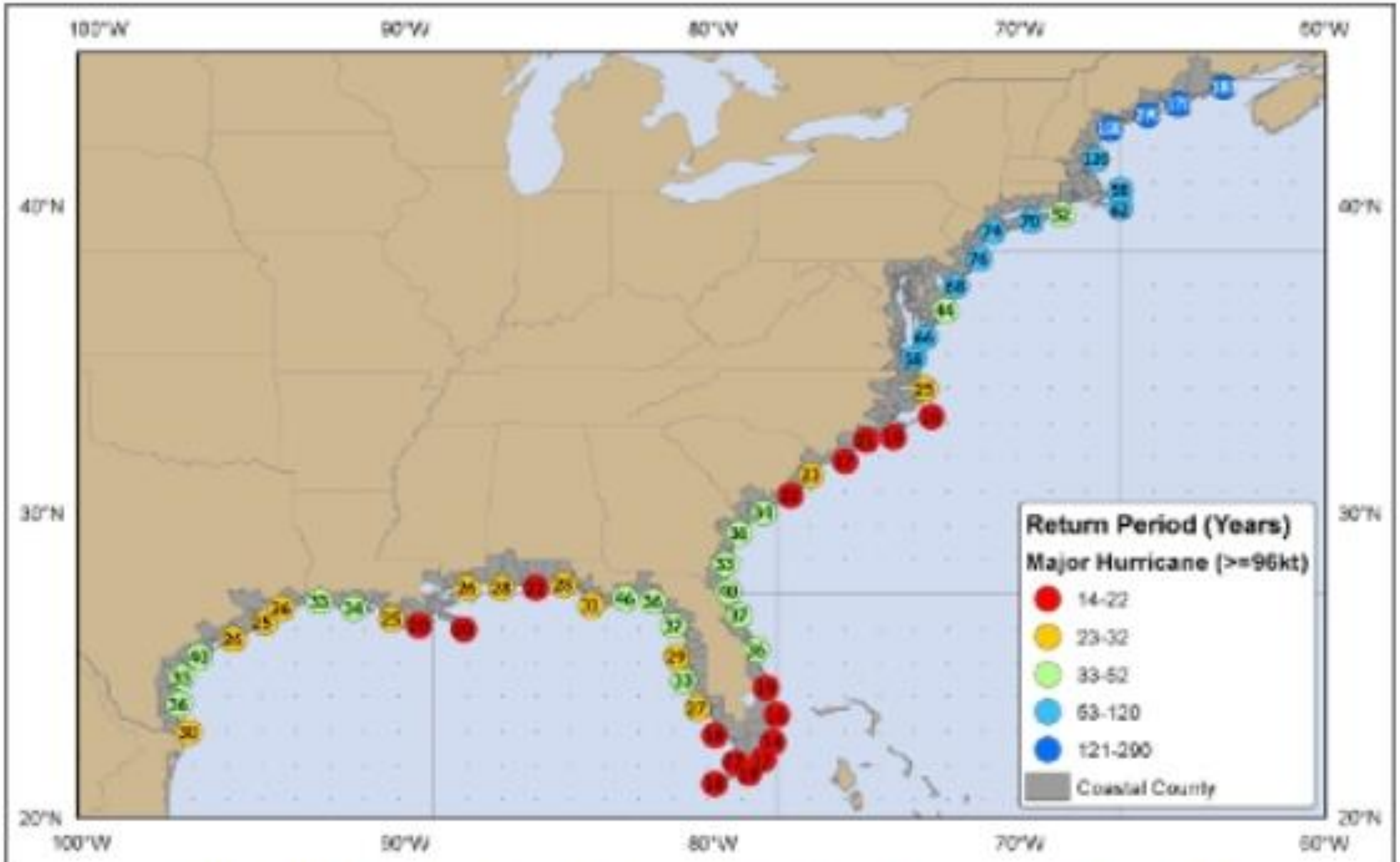


Hurricane Return Periods

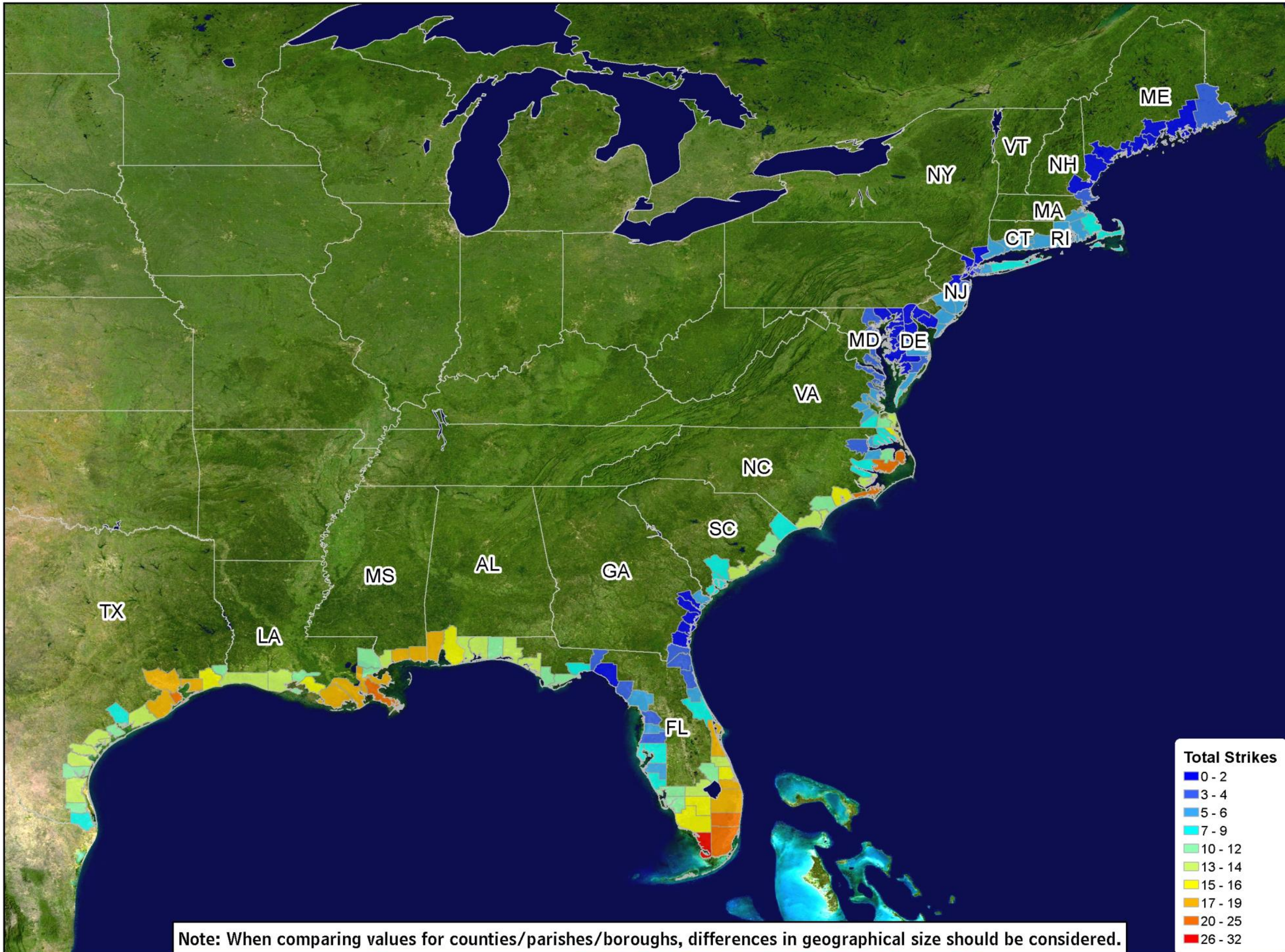
Hurricane return periods are the frequency at which a certain intensity of hurricane can be expected within a given distance of a given location (for the below images 50 nm or 58 statute miles). In simpler terms, a return period of 20 years for a major hurricane means that *on average* during the previous 100 years, a Category 3 or greater hurricane passed within 50 nm (58 miles) of that location about five times. We would then expect, *on average*, an additional five Category 3 or greater hurricanes within that radius over the next 100 years.



Estimated return period in years for hurricanes passing within 50 nautical miles of various locations on the U.S. Coast

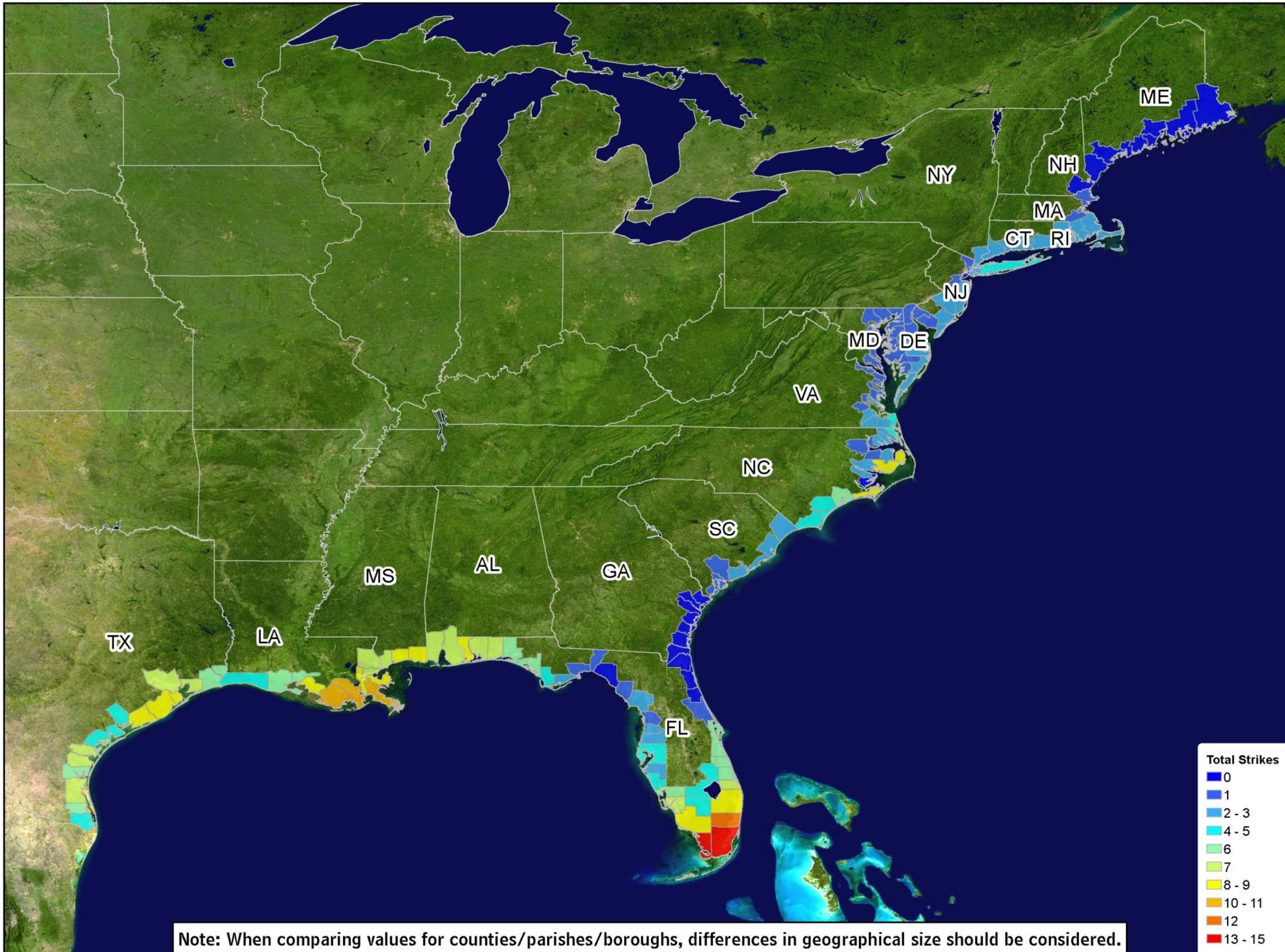


Estimated return period in years for major hurricanes passing within 50 nautical miles of various locations on the U.S. Coast



Total number of hurricane strikes by counties/parishes/boroughs, 1900-2010

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.



Total number of major hurricane strikes by counties/parishes/boroughs, 1900-2010

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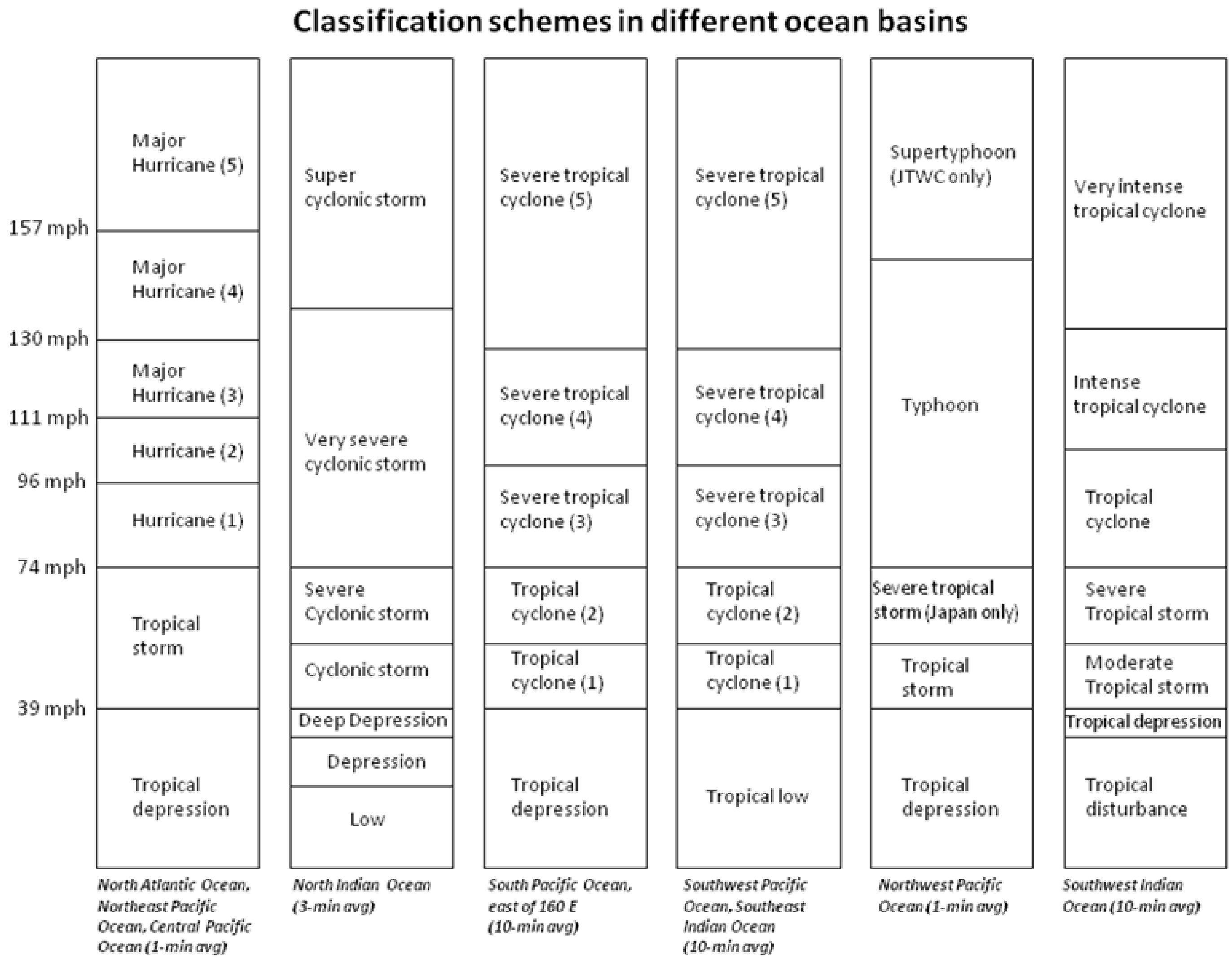


Figure 4. Classification schemes for the six ocean regions where hurricanes occur, from genesis to intense hurricanes. The U.S. definitions are used for reference on the left side. Also shown are the wind damage scales used in the U.S. and in Australia. Wind averaging schemes are shown for each basin. 1-minute averaging results in winds that are approximately 14% more than 10-minute average winds (1-minute winds=1.14 times ten-minute winds).

Table 1. Mean number total storms (hurricanes and tropical storms), hurricanes, and major hurricanes per year in all tropical ocean basins using U.S. definitions.

Tropical ocean basin	Mean annual tropical storms and hurricanes	Mean annual hurricanes	Mean major hurricanes
Northwest Pacific	26	17	8
North Pacific & Northeast Pacific	17	9	5
East Coast Australia & Southwest Pacific	10	5	2
West Coast Australia & Southeast Indian	8	4	1
North Atlantic	12	6	2
Southwest Indian	9	5	2
North Indian	5	2	Between 0 & 1
South Atlantic	0	0	0
Southeast Pacific	0	0	0
Global	86	47	20

North Atlantic

Alberto
Beryl
Chris
Debby
Ernesto
Florence
Gordon
Helene
Isaac
Joyce
Kirk
Leslie
Michael
Nadine
Oscar
Patty
Rafael
Sandy
Tony
Valerie
William

Eastern North Pacific

Aletta
Bud
Carlotta
Daniel
Emilia
Fabio
Gilma
Hector
Ileana
John
Kristy
Lane
Miriam
Norman
Olivia
Paul
Rosa
Sergio
Tara
Vicente
Willa
Xavier
Yolanda
Zeke

Central North Pacific Names

List 1	List 2	List 3	List 4
Akoni	Aka	Alika	Ana
Ema	Ekeka	Ele	Ela
Hone	Hene	Huko	Halola
Iona	Iolana	Iopa	Iune
Keli	Keoni	Kika	Kilo
Lala	Lino	Lana	Loke
Moke	Mele	Maka	Malia
Nolo	Nona	Neki	Niala
Olana	Oliwa	Omeka	Oho
Pena	Pama	Pewa	Pali
Ulana	Upana	Unala	Ulika
Wale	Wene	Wali	Walaka

Western North Pacific and the South China Sea Names (as of 2012)					
Contributor	I	II	III	IV	V
Cambodia	Damrey	Kong-rey	Nakri	Krovanh	Sarika
China	Haikui	Yutu	Fengshen	Dujuan	Haima
DPR Korea	Kirogi	Toraji	Kalmaegi	Mujigae	Meari
HK, China	Kai-Tak	Man-yi	Fung-wong	Choi-wan	Ma-on
Japan	Tembin	Usagi	Kanmuri	Koppu	Tokage
Lao PDR	Bolaven	Pabuk	Phanfone	Champi	Nock-ten
Macao, China	Sanba	Wutip	Vongfong	In-fa	Muifa
Malaysia	Jelawat	Sepat	Nuri	Melor	Merbok
Micronesia	Ewiniar	Fitow	Sinlaku	Nepartak	Nanmadol
Philippines	Maliksi	Danas	Hagupit	Lupit	Talas
RO Korea	Gaemi	Nari	Jangmi	Mirinae	Noru
Thailand	Prapiroon	Wipha	Mekkhala	Nida	Kulap
U.S.A.	Maria	Francisco	Higos	Omais	Roke
Vietnam	Son-Tinh	Lekima	Bavi	Conson	Sonca
Cambodia	Bopha	Krosa	Maysak	Chanthu	Nesat
China	Wukong	Haiyan	Haishen	Dianmu	Haitang
DPR Korea	Sonamu	Podul	Noul	Mindulle	Nalgae
HK, China	Shanshan	Lingling	Dolphin	Lionrock	Banyan
Japan	Yagi	Kajiki	Kujira	Kompasu	Washi
Lao PDR	Leepi	Faxai	Chan-hom	Namtheun	Pakhar
Macao, China	Bebinca	Peipah	Linfa	Malou	Sanvu
Malaysia	Rumbia	Tapah	Nangka	Meranti	Mawar
Micronesia	Soulik	Mitag	Soudelor	Rai	Guchol
Philippines	Cimaron	Hagibis	Molave	Malakas	Talim
RO Korea	Jebi	Neoguri	Goni	Megi	Doksuri
Thailand	Mangkhut	Rammasun	Atsani	Chaba	Khanun
U.S.A.	Utor	Matmo	Etau	Aere	Vicente
Vietnam	Trami	Halong	Vamco	Songda	Saola

Australian TCWC's Area of Responsibility (as of 2010)

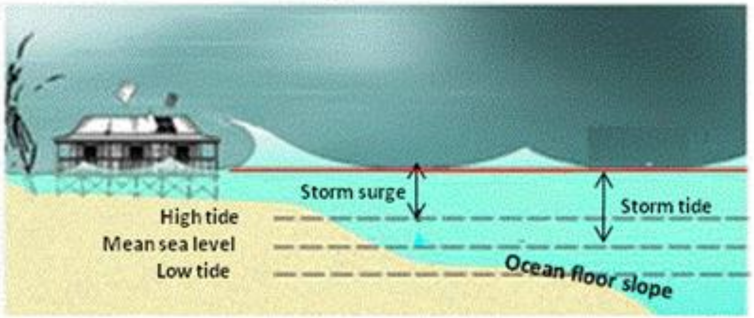
A	Anika	Anthony	Alessia	Alfred	Ann
B	Billy	Bianca	Bruce	Blanche	Blake
C	Charlotte	Carlos	Catherine	Caleb	Claudia
D	Dominic	Dianne	Dylan	Debbie	Damien
E	Ellie	Errol	Edna	Ernie	Esther
F	Freddy	Fina	Fletcher	Frances	Ferdinand
G	Gabrielle	Grant	Gillian	Greg	Gretel
H	Herman	Heidi	Hadi	Hilda	Harold
I	Ilsa	Iggy	Ita	Ira	Imogen
J	Jasper	Jasmine	Jack	Joyce	Joshua
K	Kirrily	Koji	Kate	Kelvin	Kimi
L	Lincoln	Lua	Lam	Linda	Lucas
M	Megan	Mitchell	Marcia	Marcus	Marian
N	Neville	Narelle	Nathan	Nora	Noah
O	Olga	Oswald	Olwyn	Owen	Odette
PQ	Paul	Peta	Quang	Penny	Paddy
R	Robyn	Rusty	Raquel	Riley	Ruby
S	Sean	Sandra	Stan	Savannah	Seth
T	Tasha	Tim	Tatjana	Trevor	Tiffany
UV	Vince	Victoria	Uriah	Veronica	Verdun
WXYZ	Zelia	Zane	Yvette	Wallace	

Southwest Indian Ocean

CYCLONE SEASON2012/2013

Names	Provided by
ANAIS	France
BOLDWIN	South Africa
CLAUDIA	Madagascar
DUMILE	Swaziland
EMANG	Botswana
FELLENG	Lesotho
GINO	Mauritius
HARUNA	Zimbabwe
IMELDA	Seychelles
JAMALA	Comores
KACHAY	Kenya
LUCIANO	Mozambique
MARIAM	Tanzania
NJAZI	Malawi
ONIAS	Zimbabwe
PELAGIE	Madagascar
QUILIRO	Comores
RICHARD	Seychelles
SOLANI	Swaziland
TAMIM	Tanzania
URILIA	South Africa
VUYANE	Lesotho
WAGNER	Kenya
XUSA	Malawi
YARONA	Botswana
ZACARIAS	Mozambique

Storm surge at high tide



Storm surge for different bathymetries

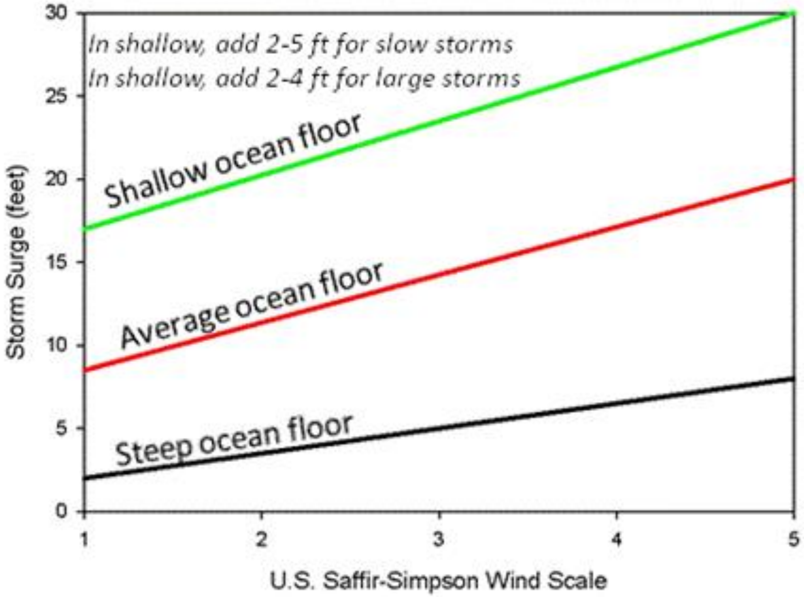
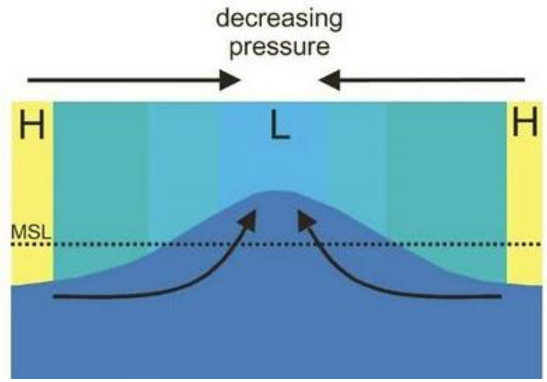


Figure 2. (Top) Graphical portrayal of the storm surge at high tide impacting a structure along a shoreline. The definition of storm tide includes the storm surge plus water elevation departures from mean sea level due to the tide cycle. Waves are superimposed on the surge. (Bottom) Storm surge relationship to ocean floor slope and hurricane intensity using the U.S. wind scale. Note the large differences between shallow and steep bathymetry for a given intensity. Storm surge is 2-5 feet higher for slow storms in shallow water, and is 2-4 feet higher for large storms in shallow water. Storm size and speed only marginally modifies surge elevation in average and steep ocean floors, and is neglected. Top figure adopted from (2). Bottom figure adopted from (3).

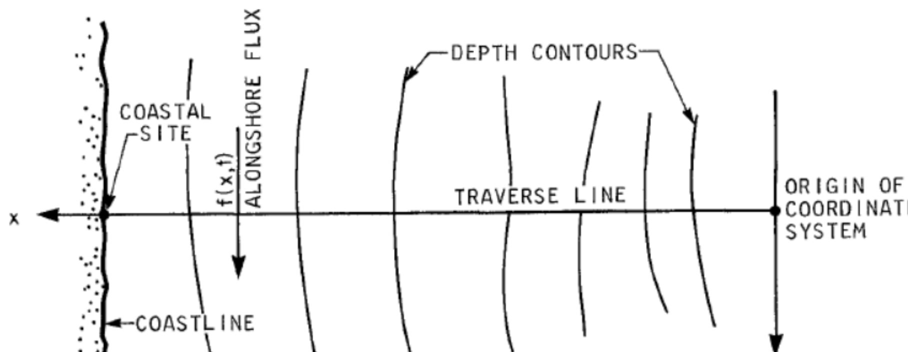
Pressure effect

(peaks at landfall)



Surge forerunner

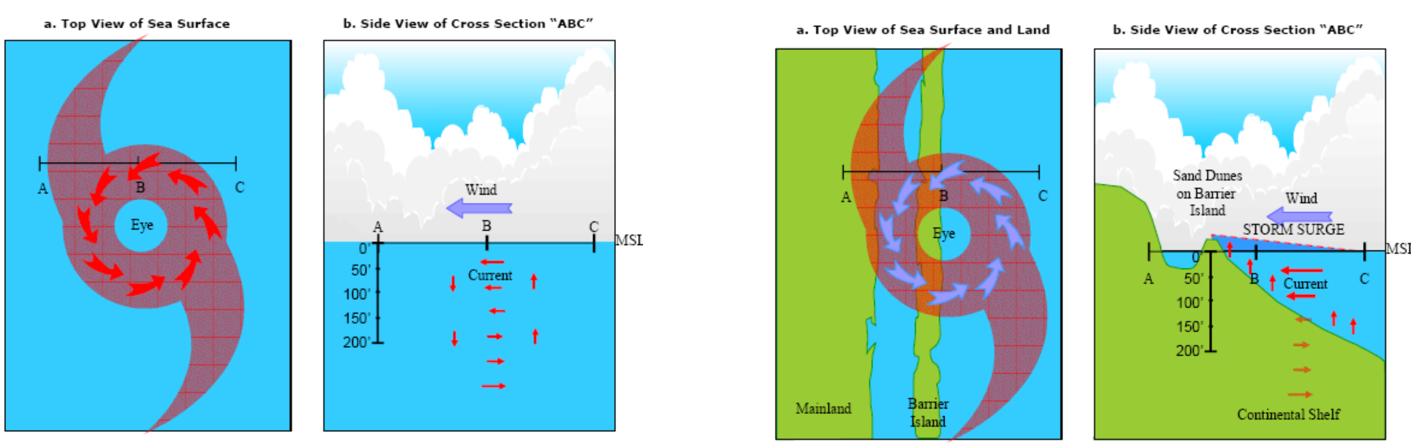
(peaks before landfall)



Ocean tilts toward coast to balance earth rotation as alongshore current forms while hurricane is offshore

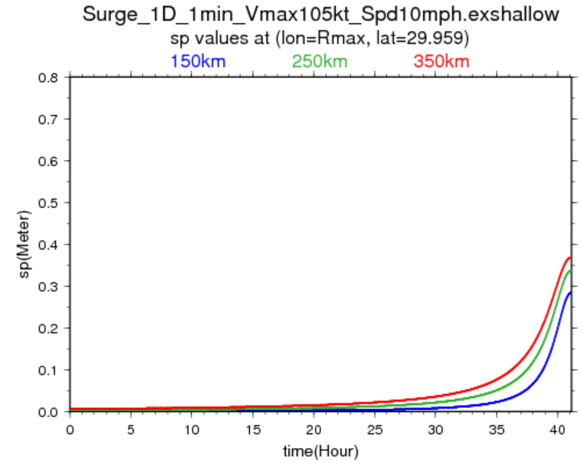
Wind effect

(peaks at landfall)



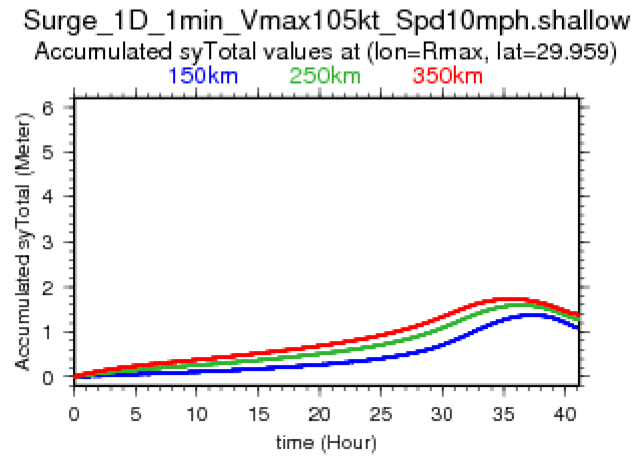
Pressure effect

(peaks at landfall)



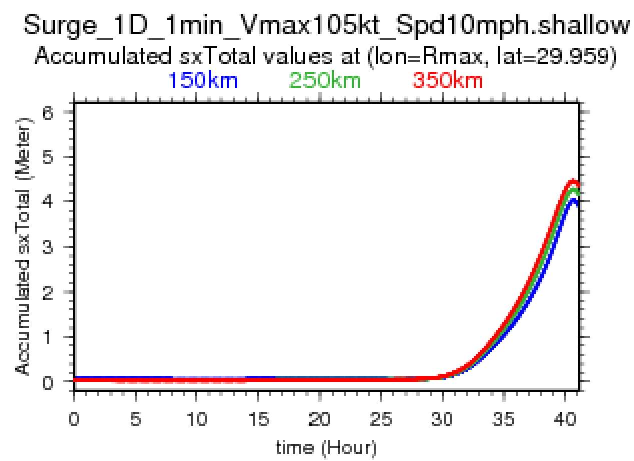
Surge forerunner

(peaks before landfall)



Wind effect

(peaks at landfall)



Time series example for Cat 3 in shallow bathymetry for small, average, and large hurricane moving 10 mph

Surge on coastline

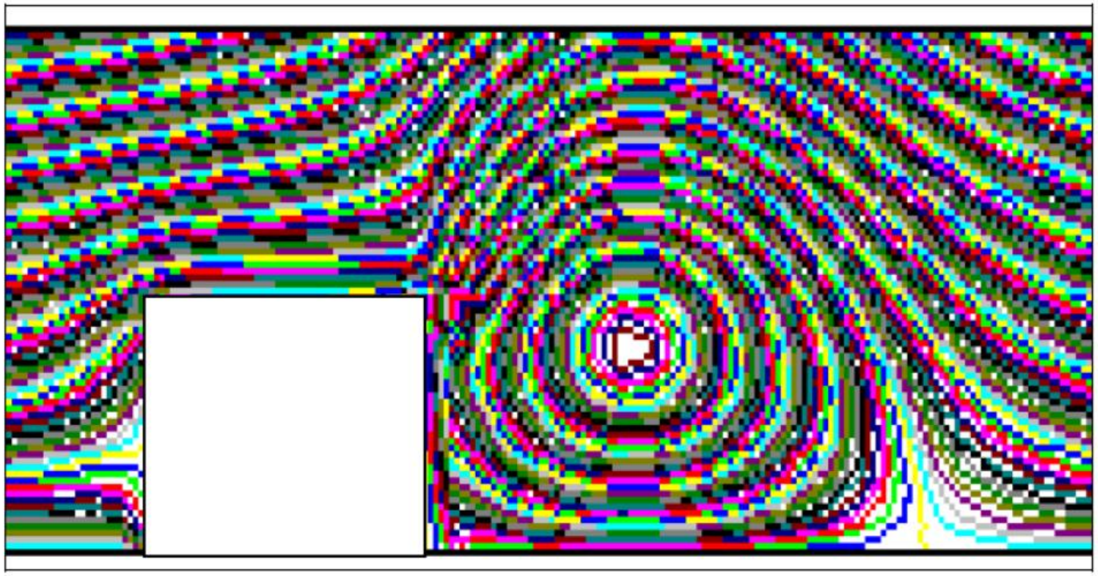
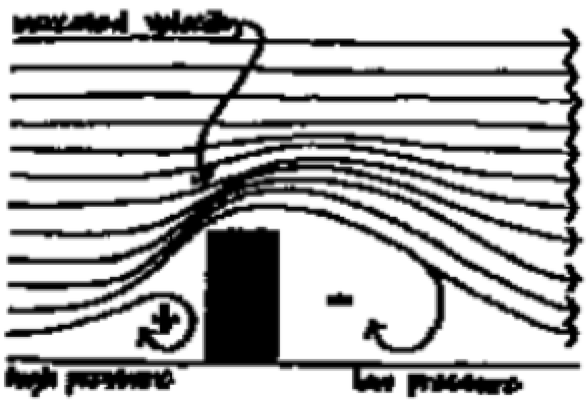
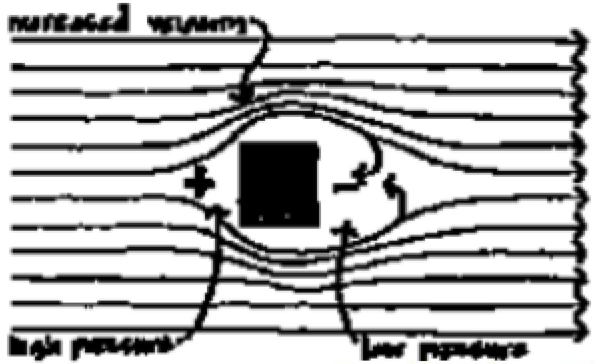
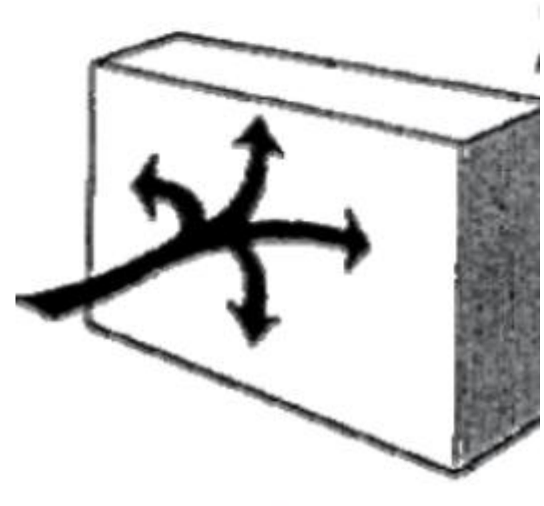


Figure 1: Streamline over 2D prismatic building







6.5.10 Velocity Pressure. Velocity pressure, q_z, evaluated at height z shall be calculated by the following equation:

$$q_z = 0.00256 K_z K_{zt} K_d V^2 I \text{ (lb/ft}^2\text{)} \qquad (6\text{-}15)$$

[In SI: $q_z = 0.613 K_z K_{zt} K_d V^2 I$ (N/m^2); V in m/s]

where K_d is the wind directionality factor defined in Section 6.5.4.4, K_z is the velocity pressure exposure coefficient defined in Section 6.5.6.6, K_{zt} is the topographic factor defined in Section 6.5.7.2, and q_h is the velocity pressure calculated using Eq. 6-15 at mean roof height h.

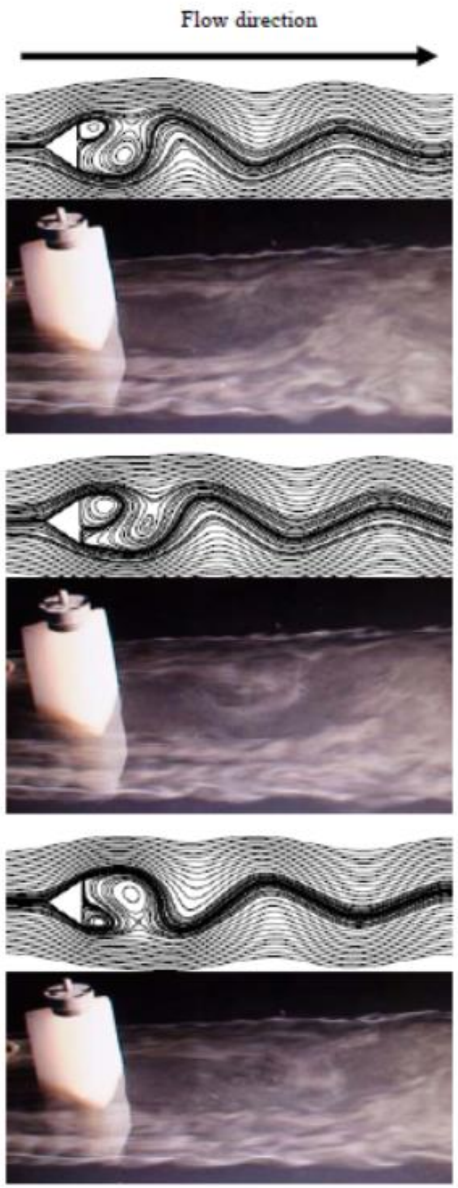

Flow direction

Table 3 Selected wind speeds, surge levels, and induced loads at the Ashe residence on September 15 and 16, 2004.

Date	Time	Sustained Wind Speed Over Water, mph	3-Second Gust speed, mph (above surge level, z)	3-Second Gust speed at mrh, mph	Still water level (SWL), ft above MSL	Significant (Maximum) Wave Height, ft	SWL + Wave Ht., ft above MSL	Wind load lb/ft	Surge load lb/ft using significant (maximum) wave height	Buoyancy pressure using significant (maximum) wave ht., psf
9/15/2004	10:30 PM	74 @ 33'			7.5	4 (6.6)	9.5 (10.8)			
9/16/2004	12:00 AM	85 @ 33 '			10.0	4 (6.6)	12.0 (13.3)			
		72 @ 10'	100 @ 10'	110	10.0	4 (6.6)	12.0 (13.3)	131	0 (0)	0 (0)
	2:00 AM	83 @ 7'	110 @ 7'	124	13.0	4 (6.6)	15.0 (16.3)	166	54 (203)	85 (170)

3-sec gust speed at mean roof height (mrh) adjusted for still water level: V(mrh-swl) = V(z)*[(mrh-swl)/z]^(1/9.5)
Mean roof height = 34.167 ft above local grade
Wind and shear loads are computed at the base of the 1st elevated floor wall
Maximum wave height = 1.66*significant wave height
First floor height = 11.167 ft above local grade (13.67' above MSL)
Wind Service Load = 184 lb/ft Wind Ultimate Load = 240 lb/ft

Class exercise, surge calculation using spreadsheet

Wind effect represented by the following Calculus equation:

$$\frac{\partial \eta}{\partial y} = \frac{(3.4X10^{-7})W^2}{(h+\eta)}$$

Which can be approximated as:

$$\eta_{i+1} = \eta_i + \frac{\Delta y(3.4X10^{-7})W^2}{(h_i+\eta_i)}$$

Assume the ocean floor has a linear slope represented as

$$h_i = h_{i+1} + m(y_i - y_{i+1})$$

1) Vary the ocean slope m and wind speed W
2) Convert the storm surge from meters to feet in a new column