Hot Science Cool Talks

UT Environmental Science Institute

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Hurricanes in the Gulf of Mexico: The History and Future of the Texas Coast

Dr. Kerry Emanuel

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Hurricanes in the Gulf of Mexico: The History and Future of the Texas Coast

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Massachusetts Institute of Technology

Image: NASA

Program

- Overview of hurricanes
- History of Texas hurricanes
- Texas hurricane risk, present and future

Overview of Hurricanes

Image: NASA

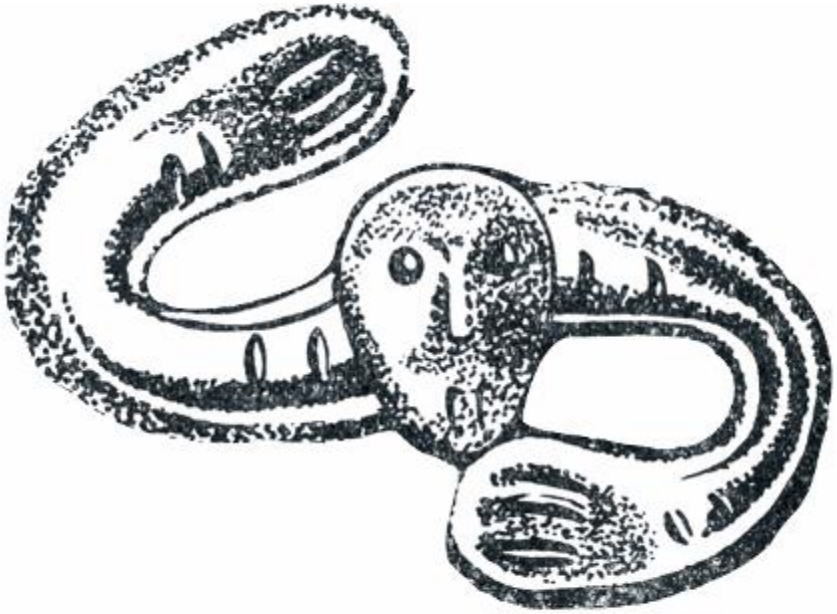
What is a Hurricane?

Image: NOAA

Formal definition:

A *tropical cyclone* with 1-minute average winds at 10 meter altitude in excess of 32 meters/second (64 knots or 74 miles per hour) occurring over the North Atlantic or eastern North Pacific

The word *Hurricane* is derived from the Mayan word *Huracan* and the Taino and Carib word *Hunraken*, a terrible God of Evil, and brought to the West by Spanish explorers



The View from Space

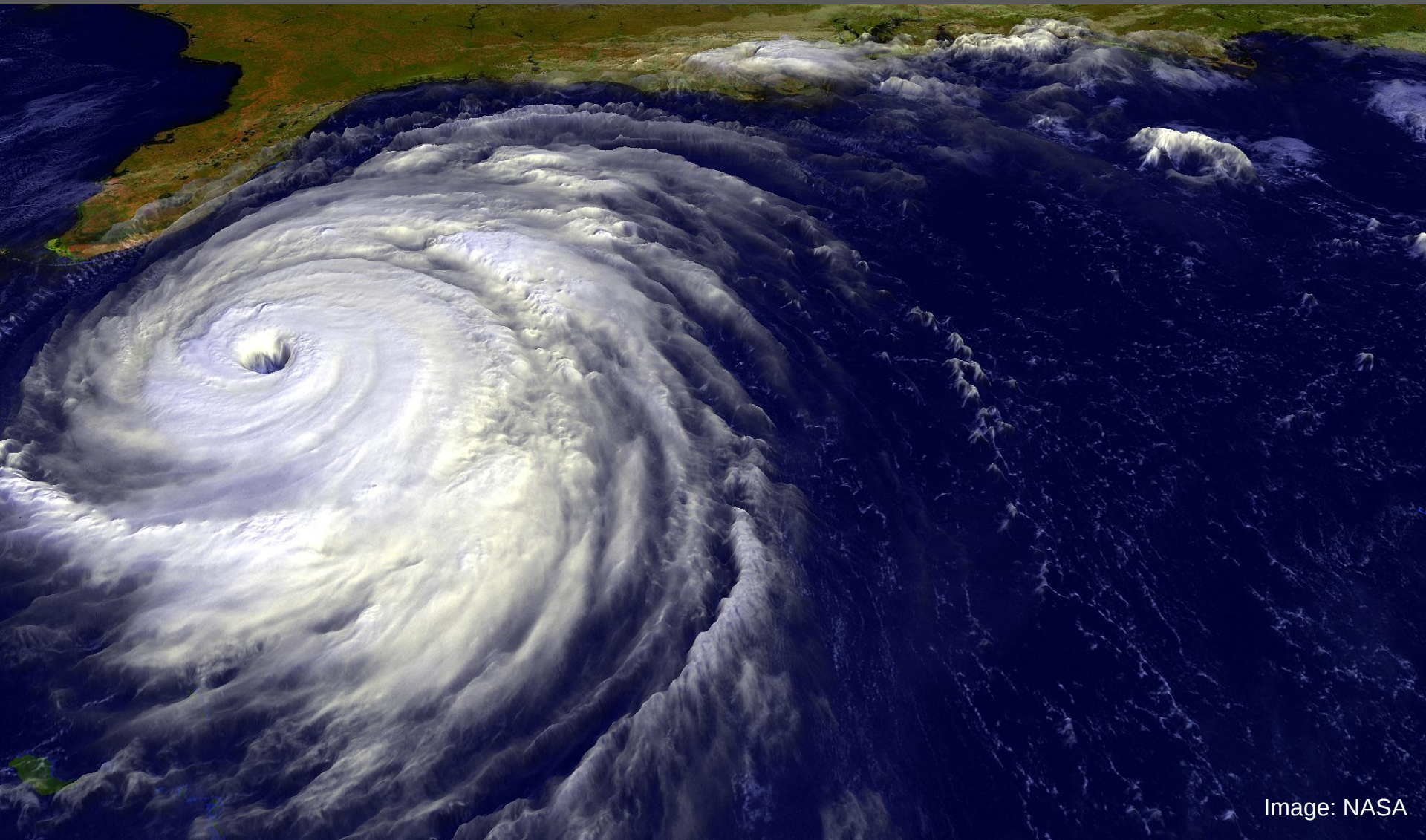


Image: NASA


Hurricane Ike
GOES-12 IR
September 12, 2008
HURRICANE 'IKE' 12 SEP 08 19:55Z

Igor, 2010

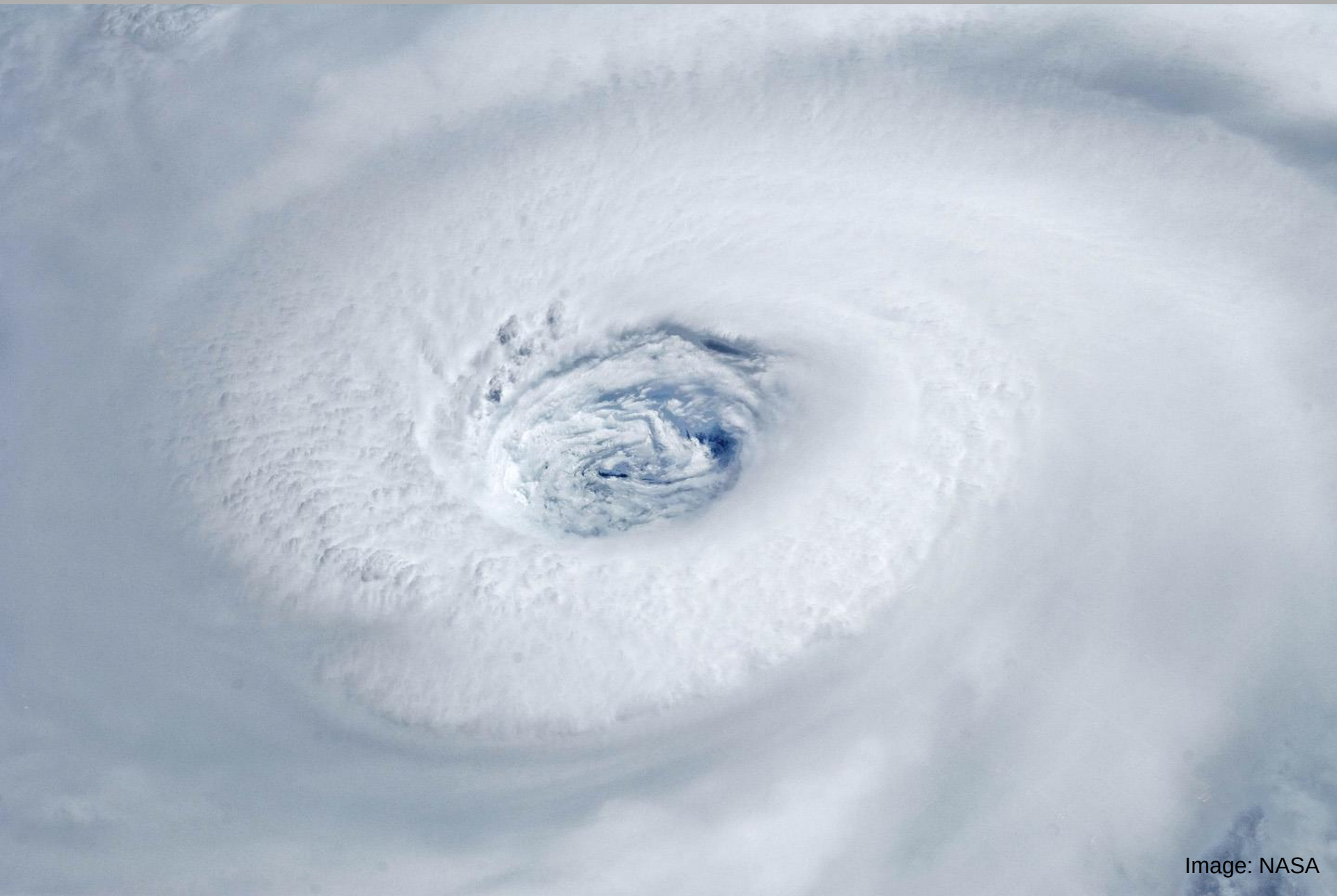


Image: NASA

Emelia, 1994

Image: NASA

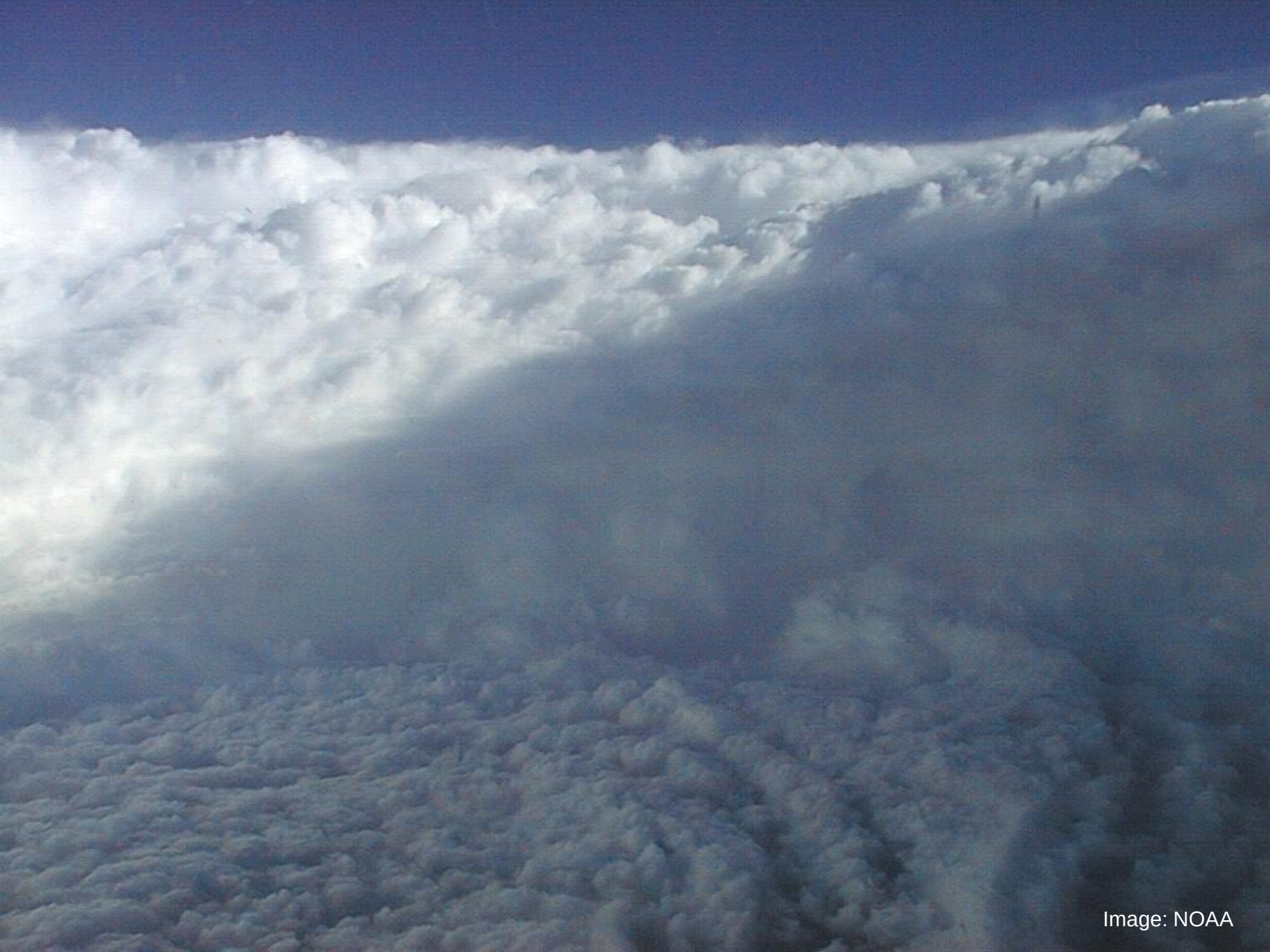
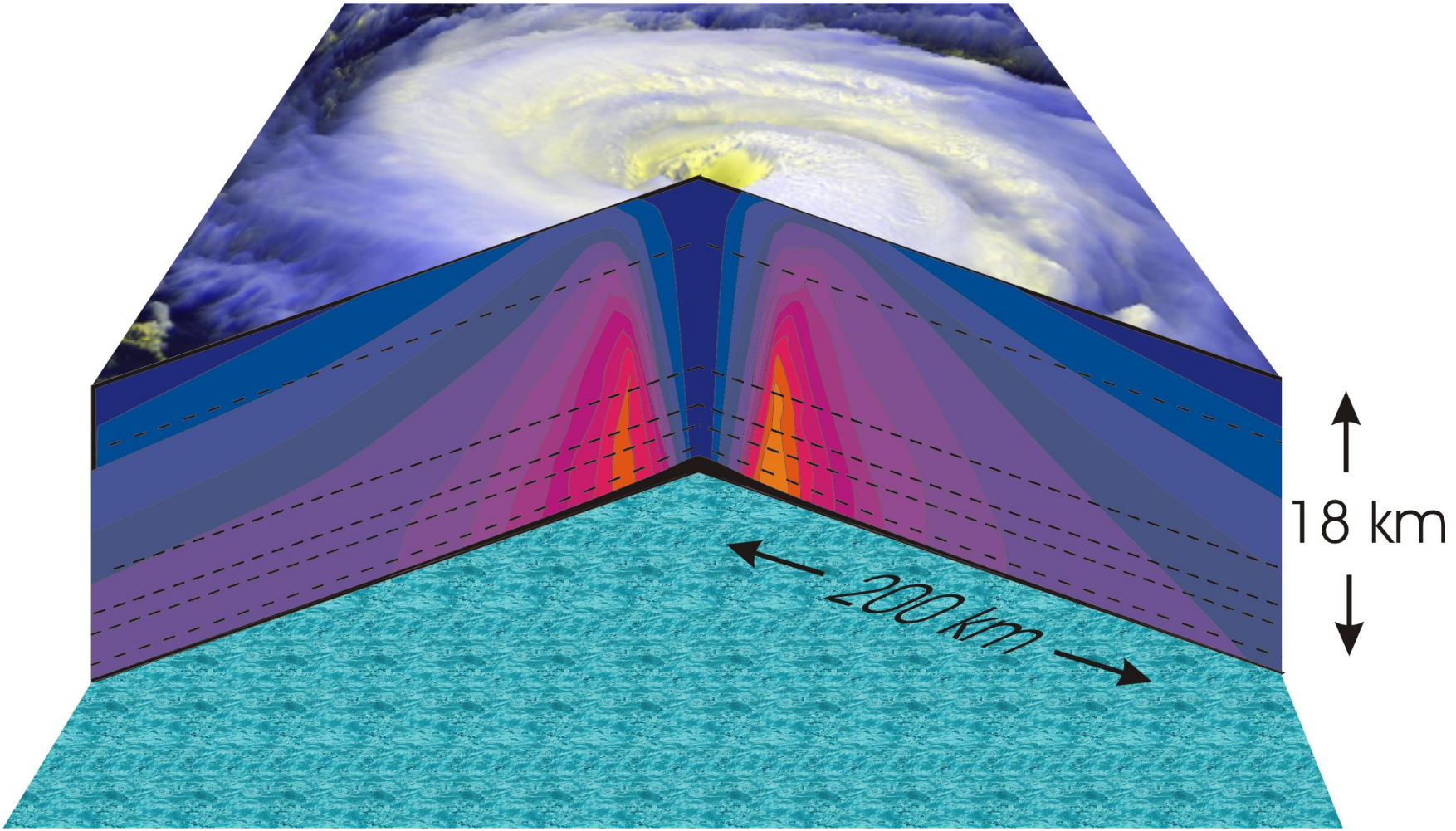


Image: NOAA

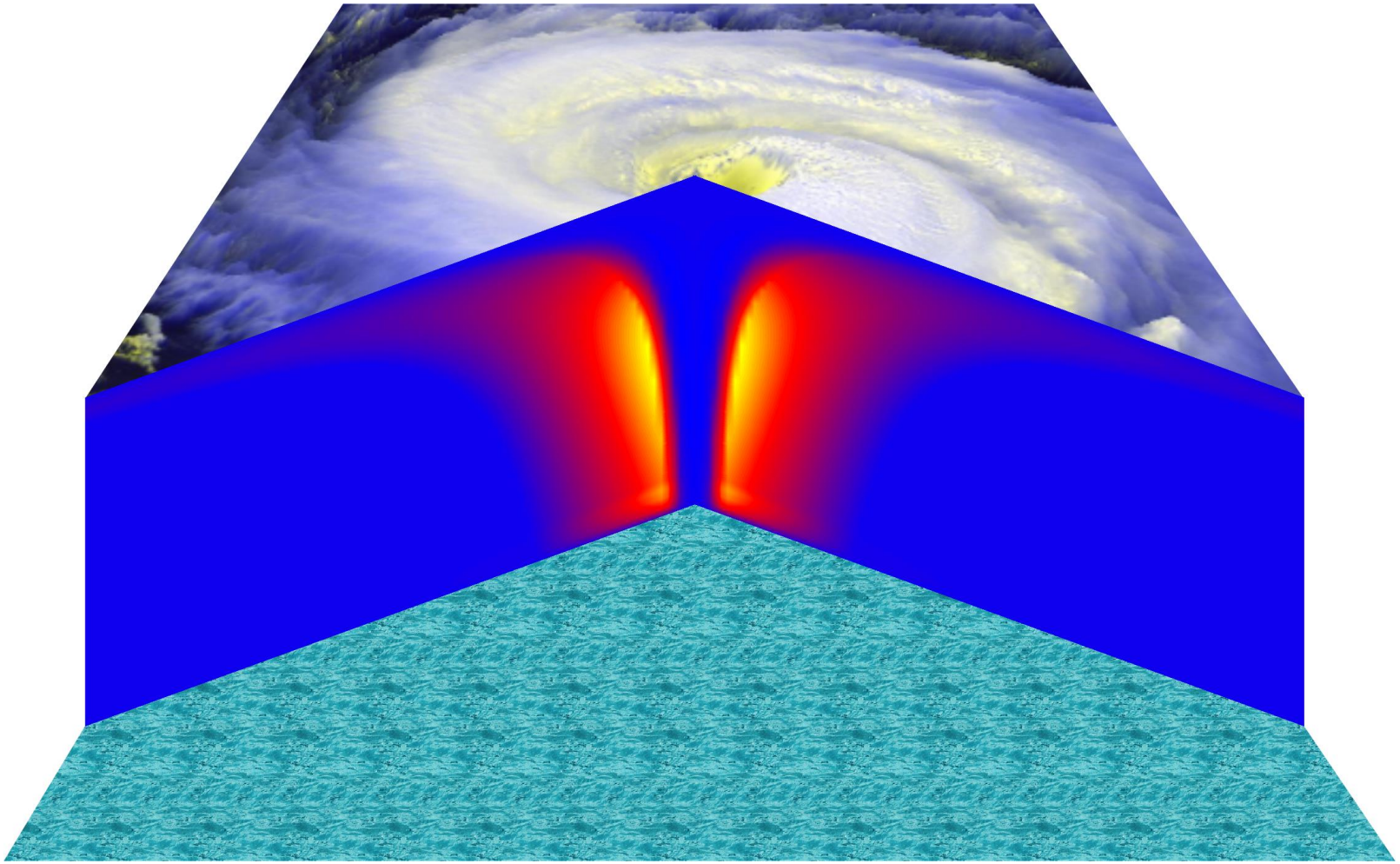
Hurricane Structure: Wind Speed



Azimuthal component of wind

< 11 mph - > 145 mph

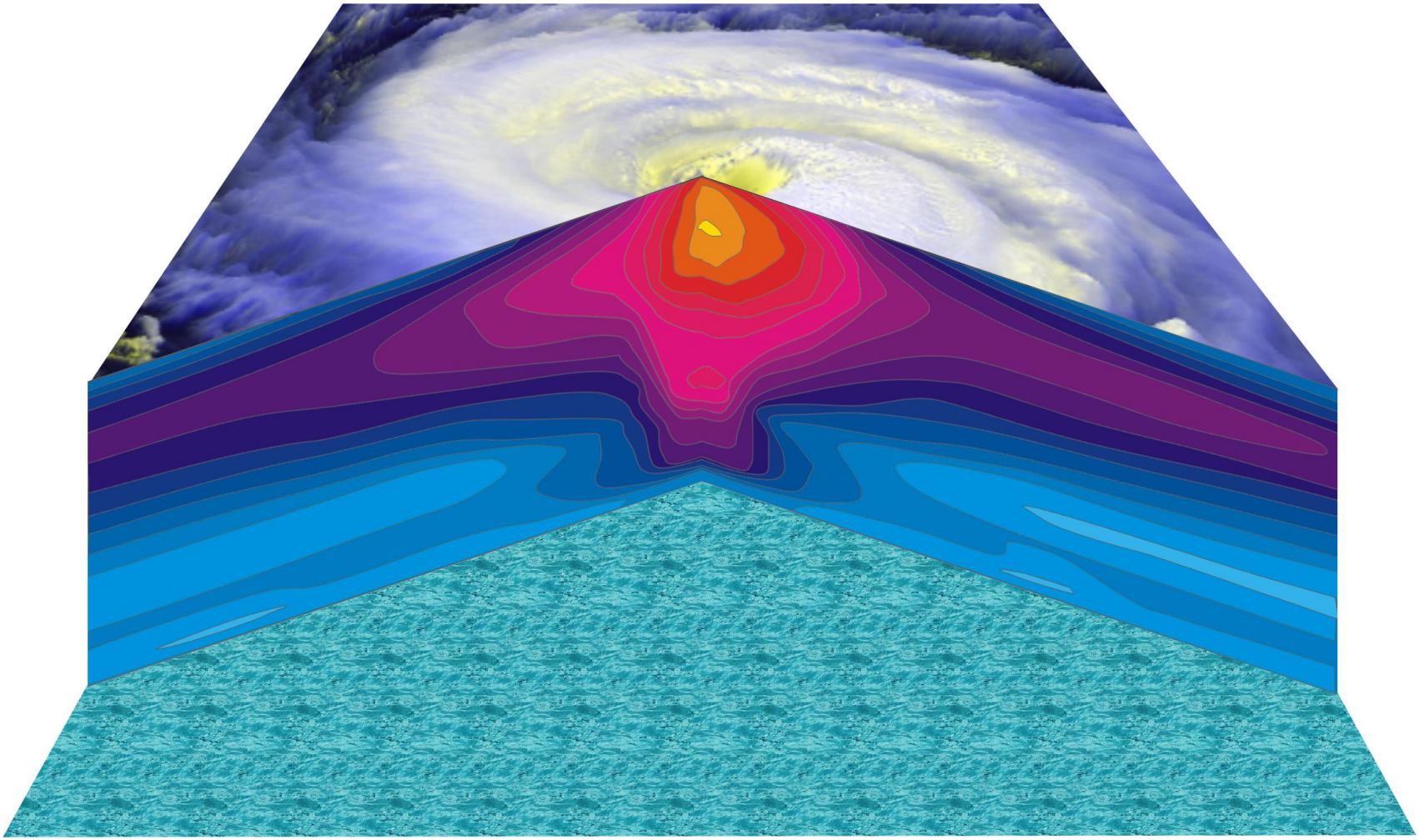
Vertical Air Motion



Updraft Speed

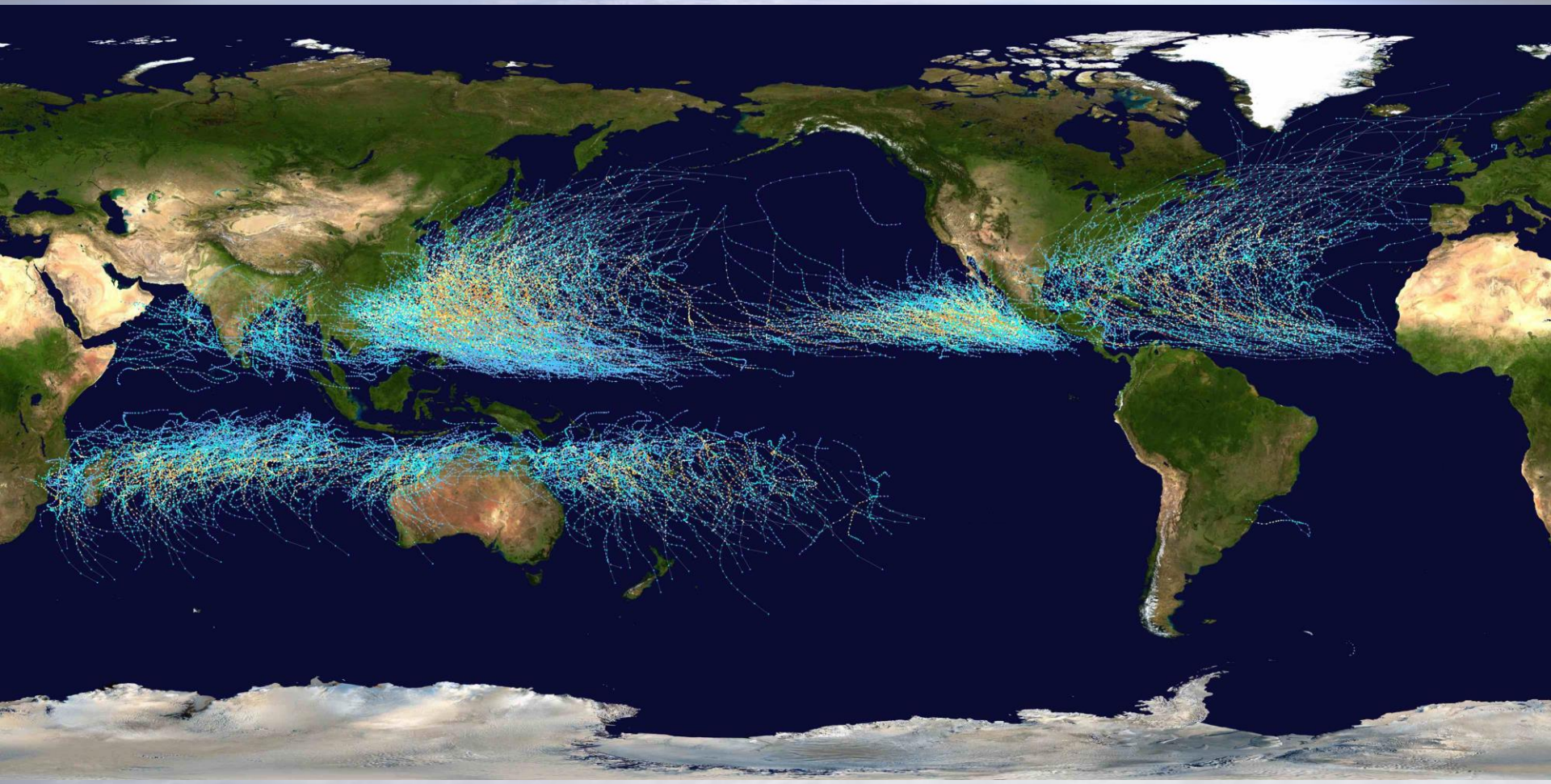
Strong upward motion in the eyewall

Hurricane Temperature Perturbations



No temperature difference - > 16°C (29°F) warmer

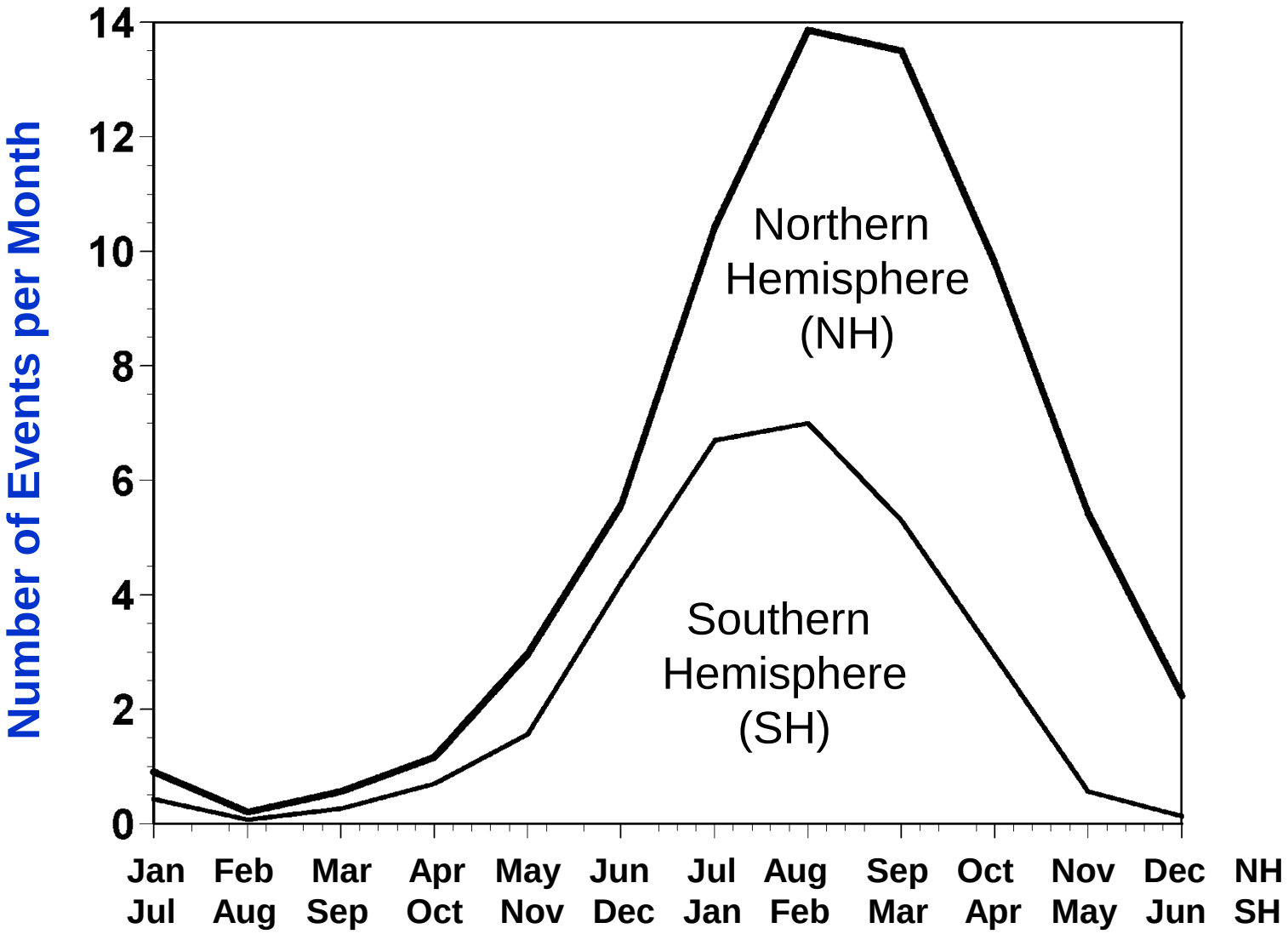
Tracks of all tropical cyclones, 1985-2005



Source: Wikipedia

Image: NASA

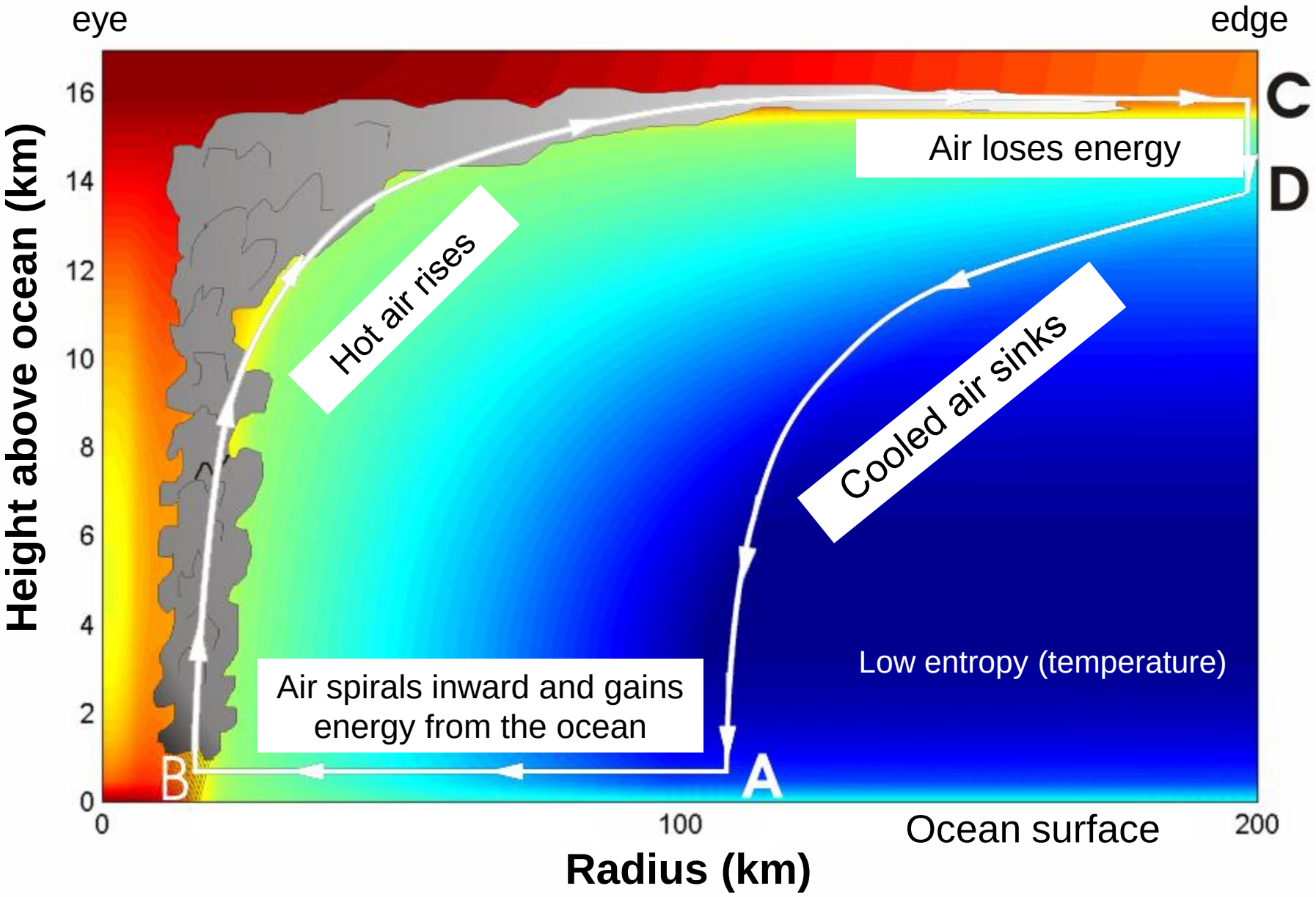
Annual Cycle of Tropical Cyclones



We First Need to Know How Hurricanes Work

Image: NASA

Cross-section through a Hurricane & Energy Production

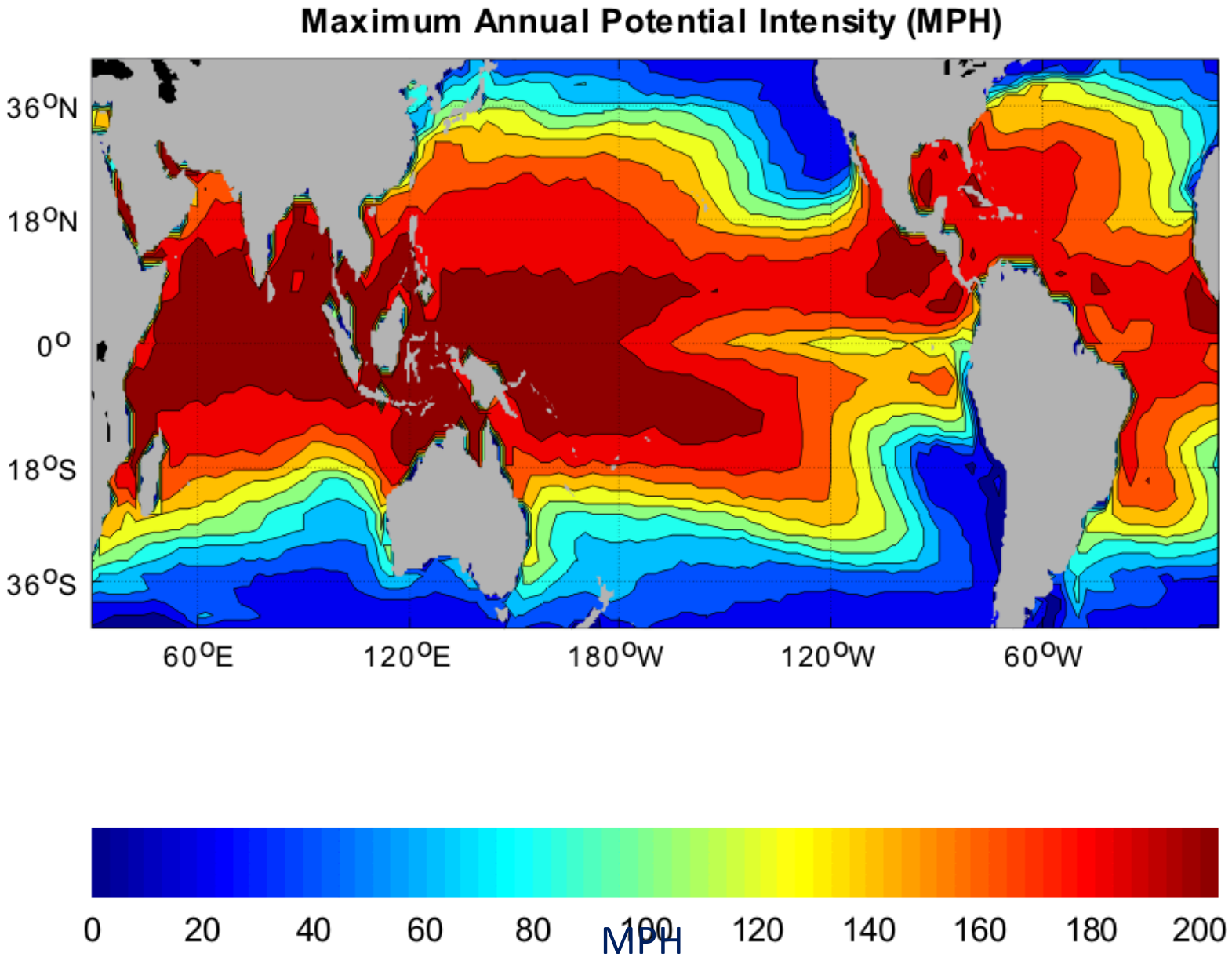


Energy Cycle gives Maximum Hurricane Wind Speed

This depends on:

- Magnitude of the greenhouse effect
- Sea surface temperature
- Temperature high up in the atmosphere
- Average speed of the trade winds within which hurricanes form

Heat Engine Theory Predicts Maximum Hurricane Winds




US Dept of State Geographer
© 2012 Google
© 2009 GeoBasis-DE/BKG
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth
Eye alt 6533.78 mi

Notable Texas Hurricanes

see:
http://www.hpc.ncep.noaa.gov/research/txhur.pdf

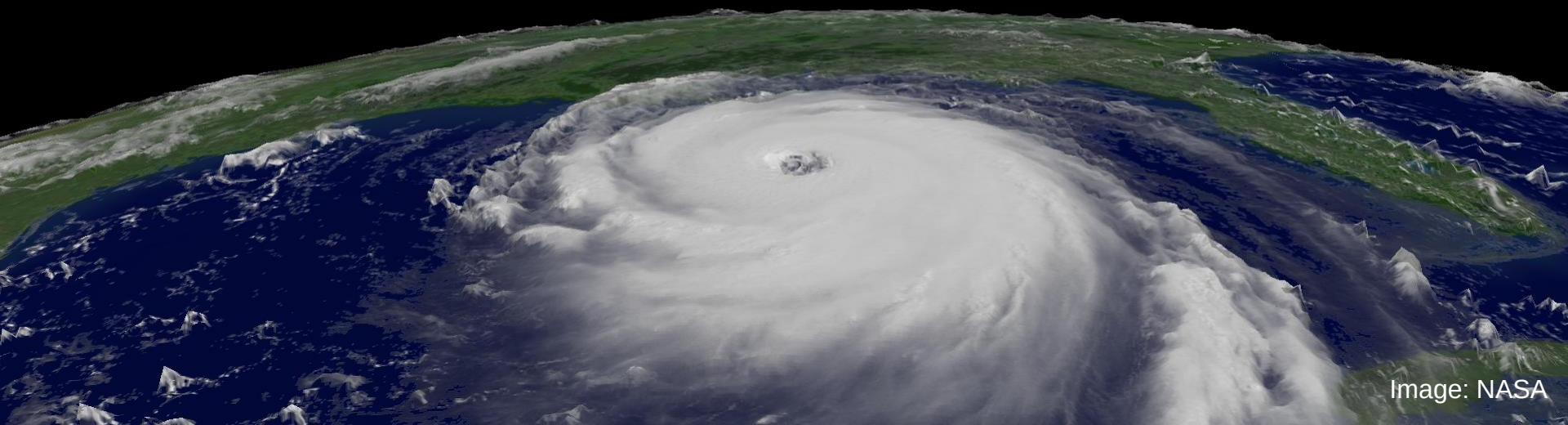
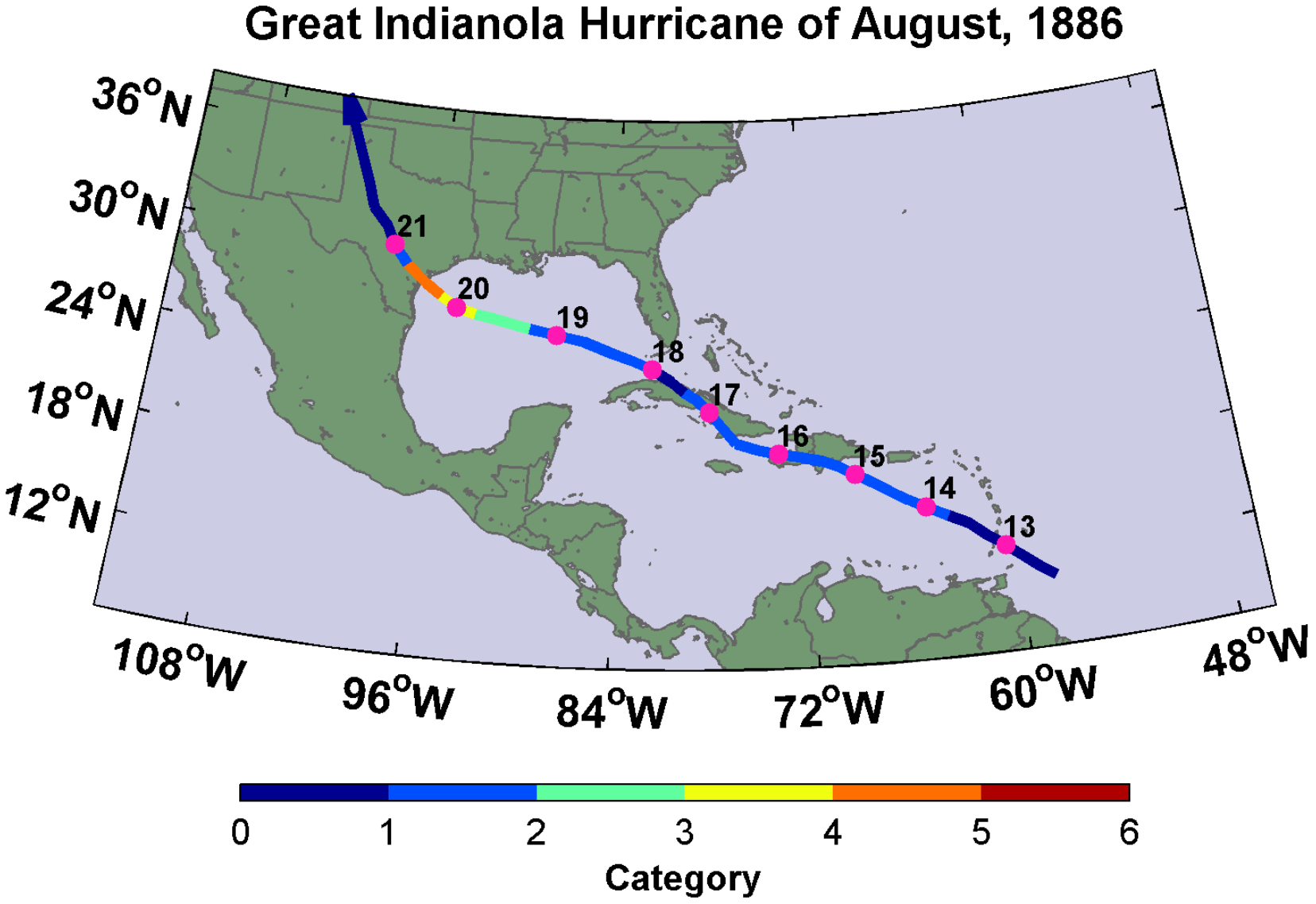


Image: NASA


Great Indianola Hurricane of August, 1886
36°N
30°N
24°N
18°N
12°N
108°W
96°W
84°W
72°W
60°W
48°W
21
20
19
18
17
16
15
14
13
0
1
2
3
4
5
6
Category

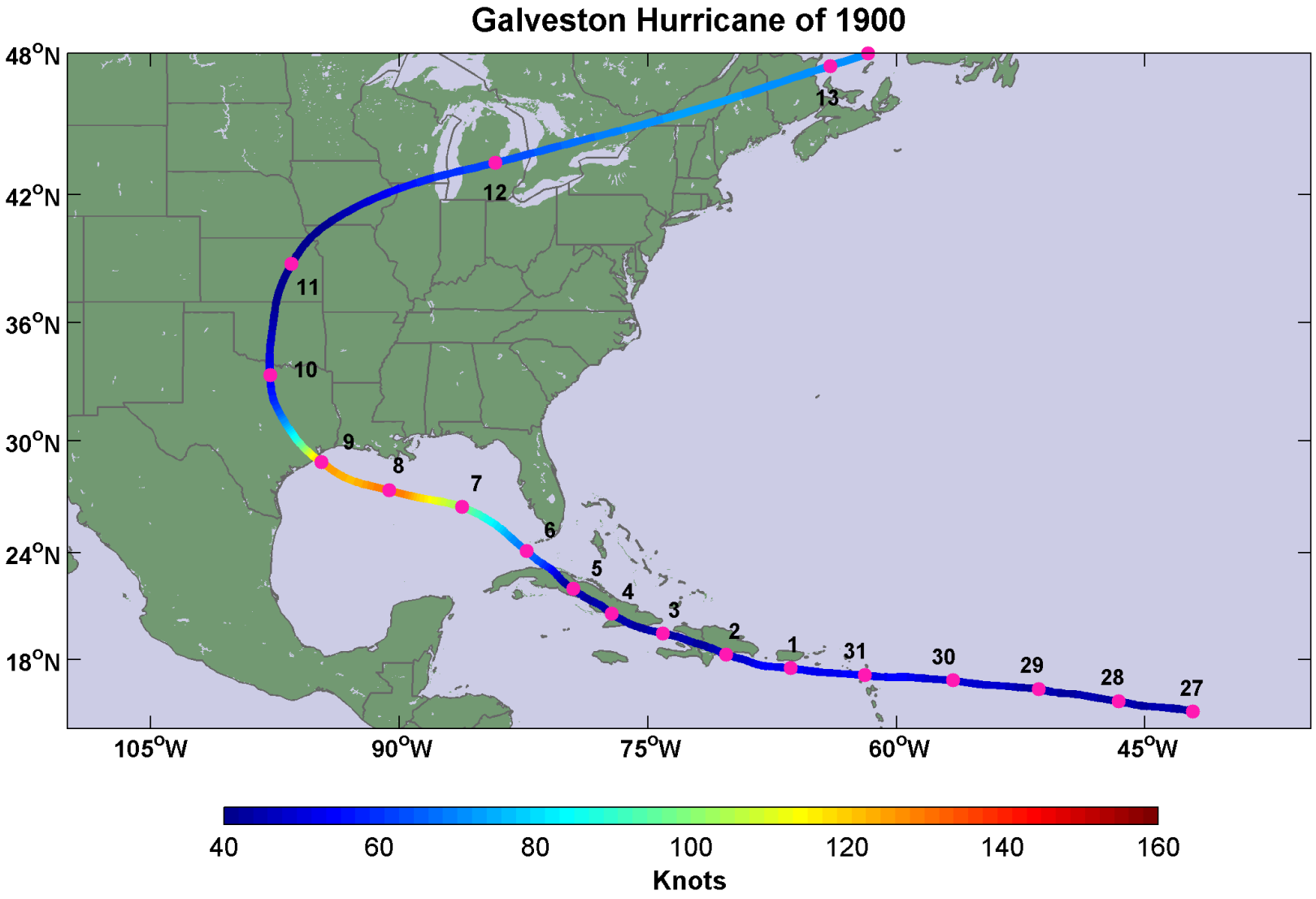
Galveston, 1900

The opinion held by some who are unacquainted with the actual conditions of things, that Galveston will at some time be seriously damaged by some such disturbance, is simply an absurd delusion

- Isaac Cline, Local Forecast Official and Section Director, U.S Weather Bureau, Galveston, Texas, in *The Galveston News*, 1891

August 28th, 1900: Willis Moore, Head of the United States Weather Bureau, issues an edict banning the transmission of all West Indian storm reports from its own Havana office to its New Orleans office. It also forbade chief forecasters from issuing hurricane warnings without prior approval from Washington. Moore followed up with a message delivered through Western Union:

The United States Weather Bureau in Cuba has been greatly annoyed by independent observatories securing a few scattered reports and then attempting to make weather predictions and issue hurricane warnings to the detriment of commerce and the embarrassment of the Government service. I have reason to believe that they are copying, or contemplate doing so, data from our daily weather maps in New Orleans and cabling the same to Havana.

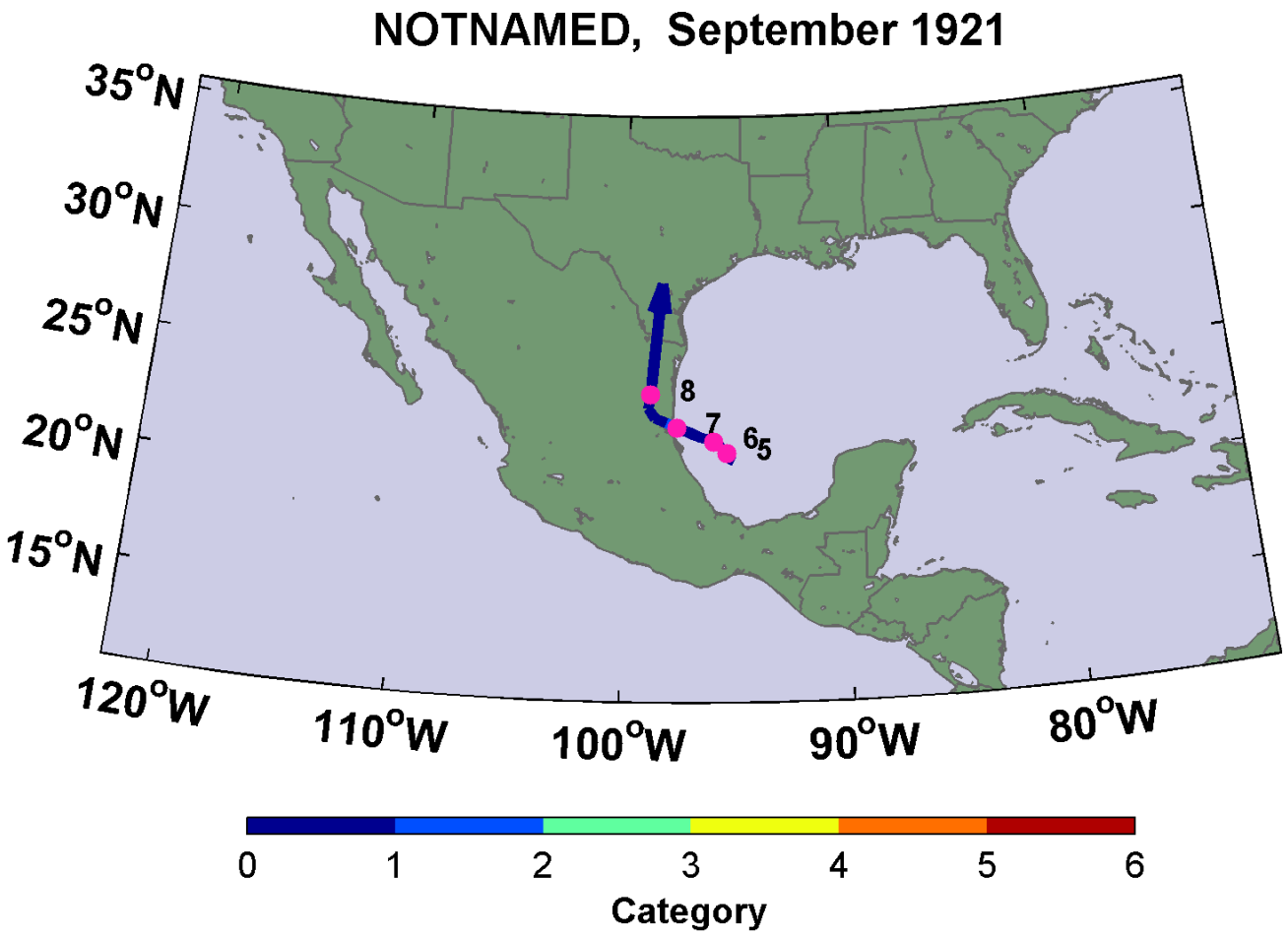

Galveston Hurricane of 1900
48°N
42°N
36°N
30°N
24°N
18°N
105°W
90°W
75°W
60°W
45°W
13
12
11
10
9
8
7
6
5
4
3
2
1
31
30
29
28
27
40
60
80
100
120
140
160
Knots

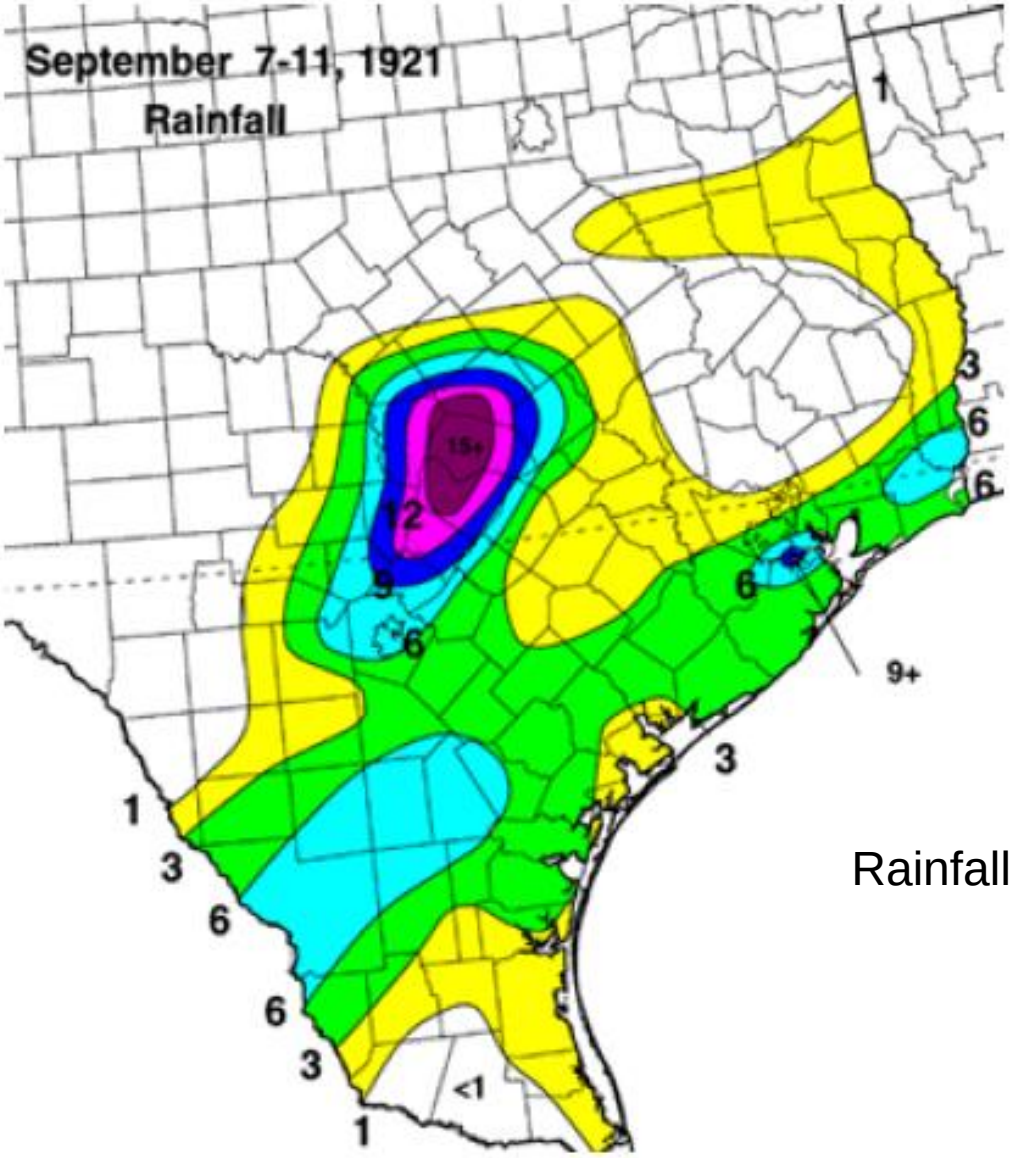
The storm will probably continue slowly northward and its effects will be felt as far as the lower portion of the middle Atlantic coast by Friday night.

- Forecast issued by U.S. Weather Bureau,
  8:00 AM Thursday, September 6, 1900

Sunday, September 9, 1900, revealed one of the most horrible sights that ever a civilized people looked upon. - Isaac Cline

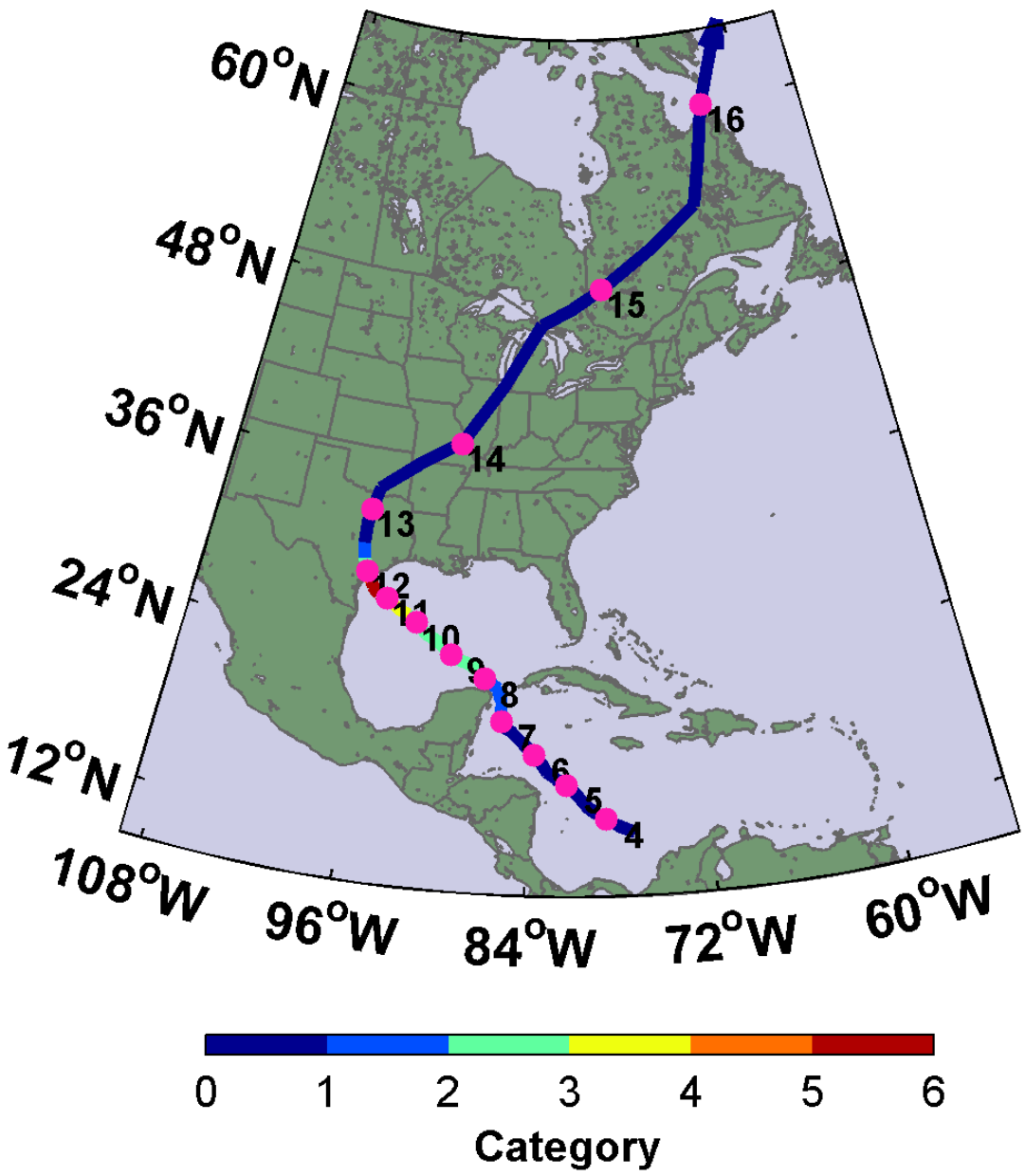
The Great San Antonio Flood of 1921

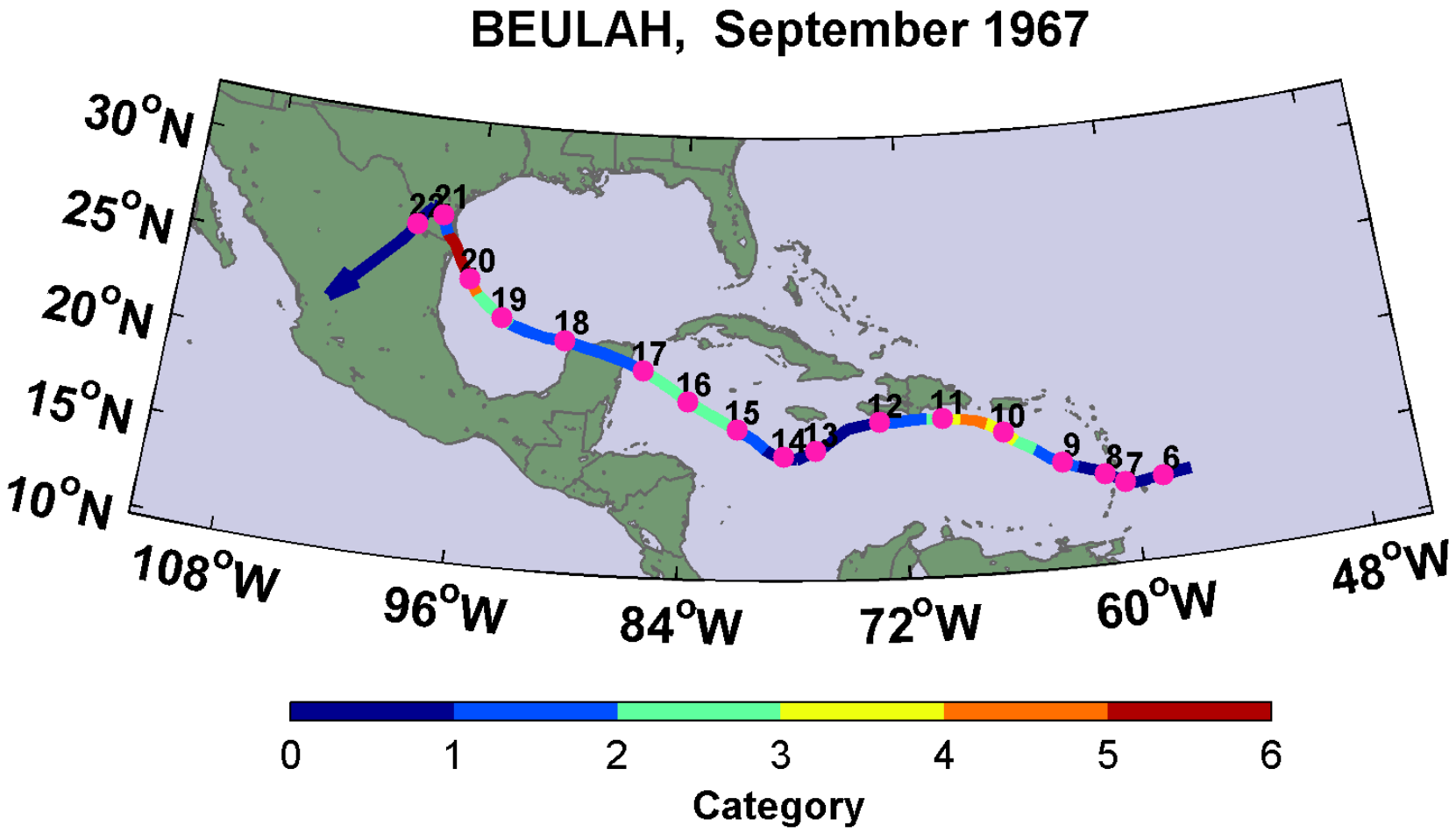




Rainfall in inches

Figure and text from "***Texas Hurricane History*",** David Roth, National Weather Service, Camp Springs, MD: http://www.hpc.ncep.noaa.gov/research/txhur.pdf


CARLA, September 1961
60°N
48°N
36°N
24°N
12°N
108°W
96°W
84°W
72°W
60°W
16
15
14
13
12
11
10
9
8
7
6
5
4
0
1
2
3
4
5
6
Category

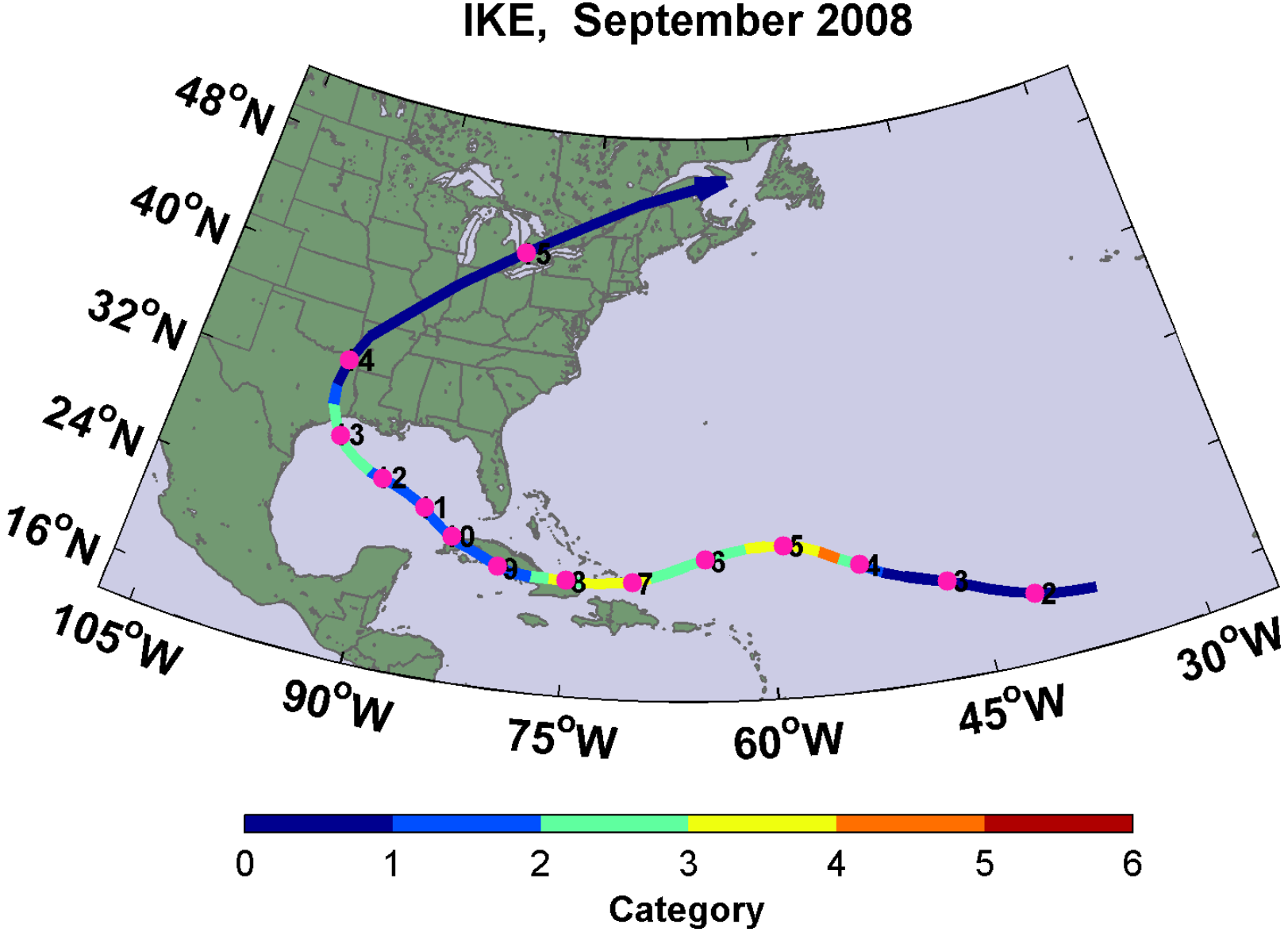

BEULAH, September 1967
30°N
25°N
20°N
15°N
10°N
108°W
96°W
84°W
72°W
60°W
48°W
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
0
1
2
3
4
5
6
Category

Hurricane Katrina, 2005

- ***A major hurricane could swamp New Orleans under 20 feet of water, killing thousands. Human activities along the Mississippi River have dramatically increased the risk, and now only massive reengineering of southeastern Louisiana can save the city***

  -- Mark Fischetti, “Drowning New Orleans”, *Scientific American*, October, 2001

Image: wikipedia


IKE, September 2008
48°N
40°N
32°N
24°N
16°N
105°W
90°W
75°W
60°W
45°W
30°W
0
1
2
3
4
5
6
Category

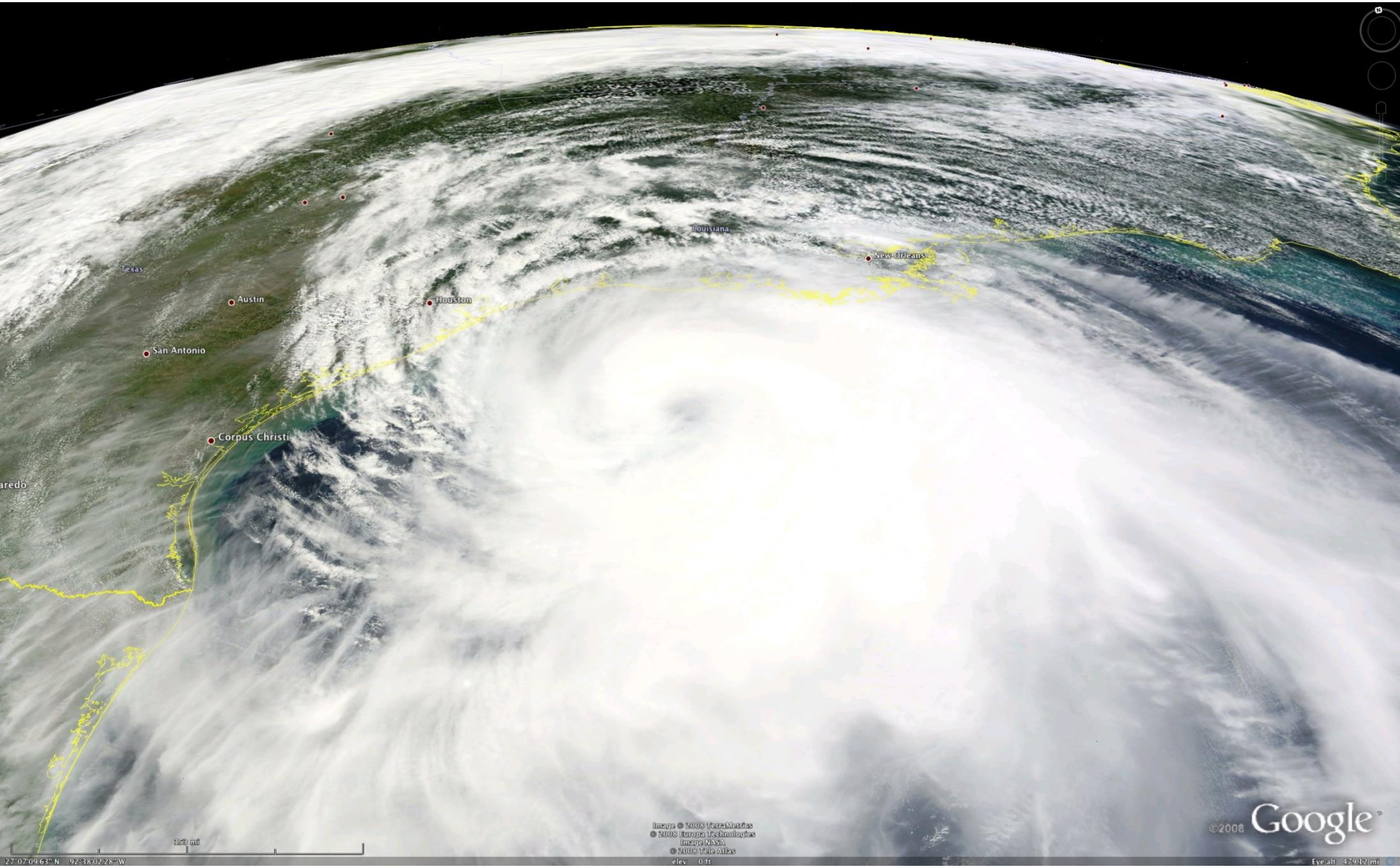


Image source: NASA

Image: buttercuppunch.wordpress.com

Assessing Texas Hurricane Risk: Present and Future

Image: NASA

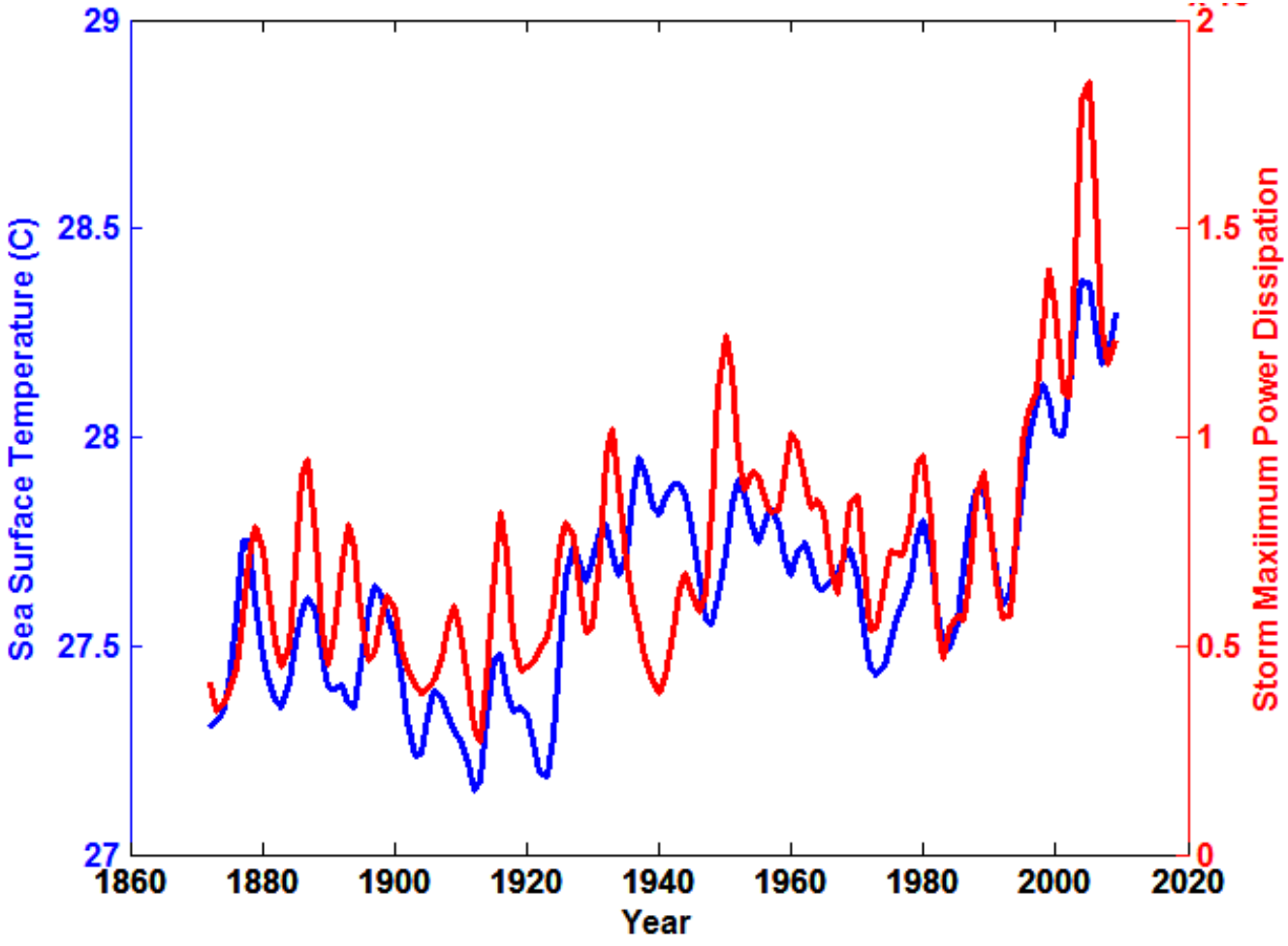
Limitations of a strictly statistical approach

- >50% of all damage caused by **top 8 events**, all category 3, 4 and 5
- **>90%** of all damage caused by storms of category **3** and greater
- Category 3,4 and 5 events are only 13% of total landfalling events; only 30 since 1870
- Thus ***There are too few hurricanes in history to make really good estimates of hurricane risk***

Additional Problem: Climate Change

Atlantic Sea Surface Temperatures and Storm Max Power Dissipation

(Smoothed with a 1-3-4-3-1 filter)



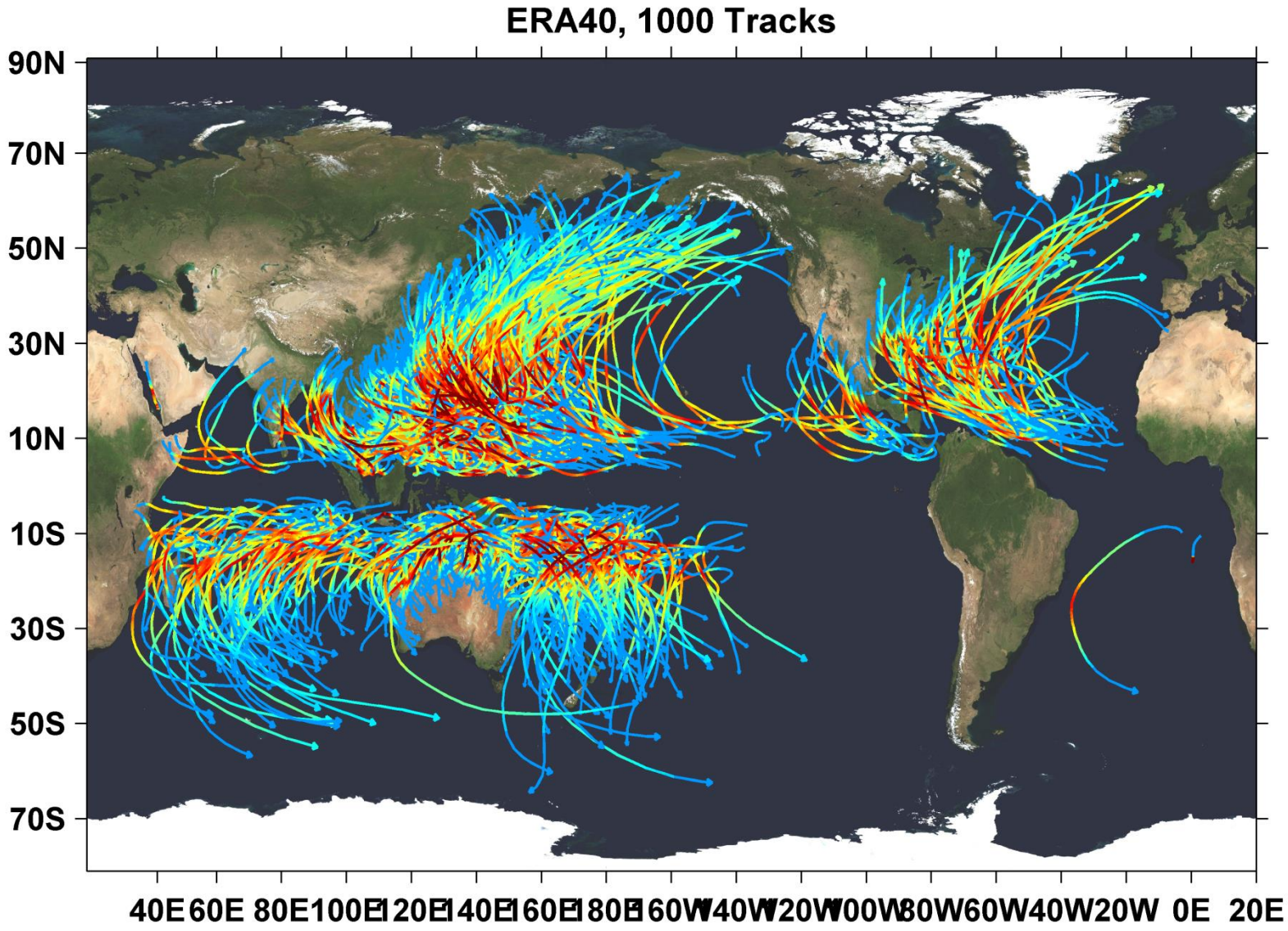
Years included: 1870-2011

Data Sources: Hurricanes: NOAA/TPC; Sea Surface Temperatures: UKMO/HADSST1

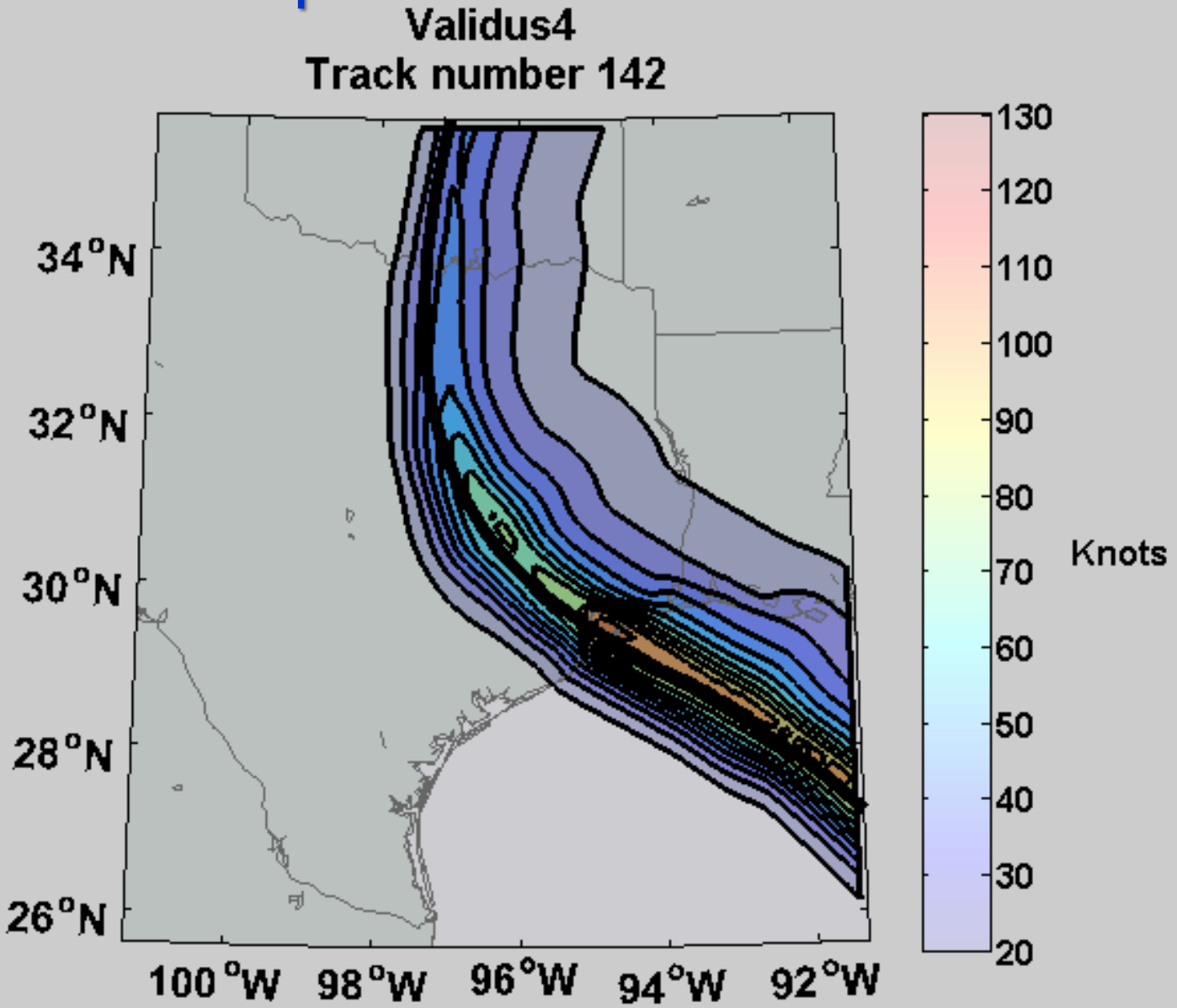
Our Approach to Hurricane Risk Assessment:

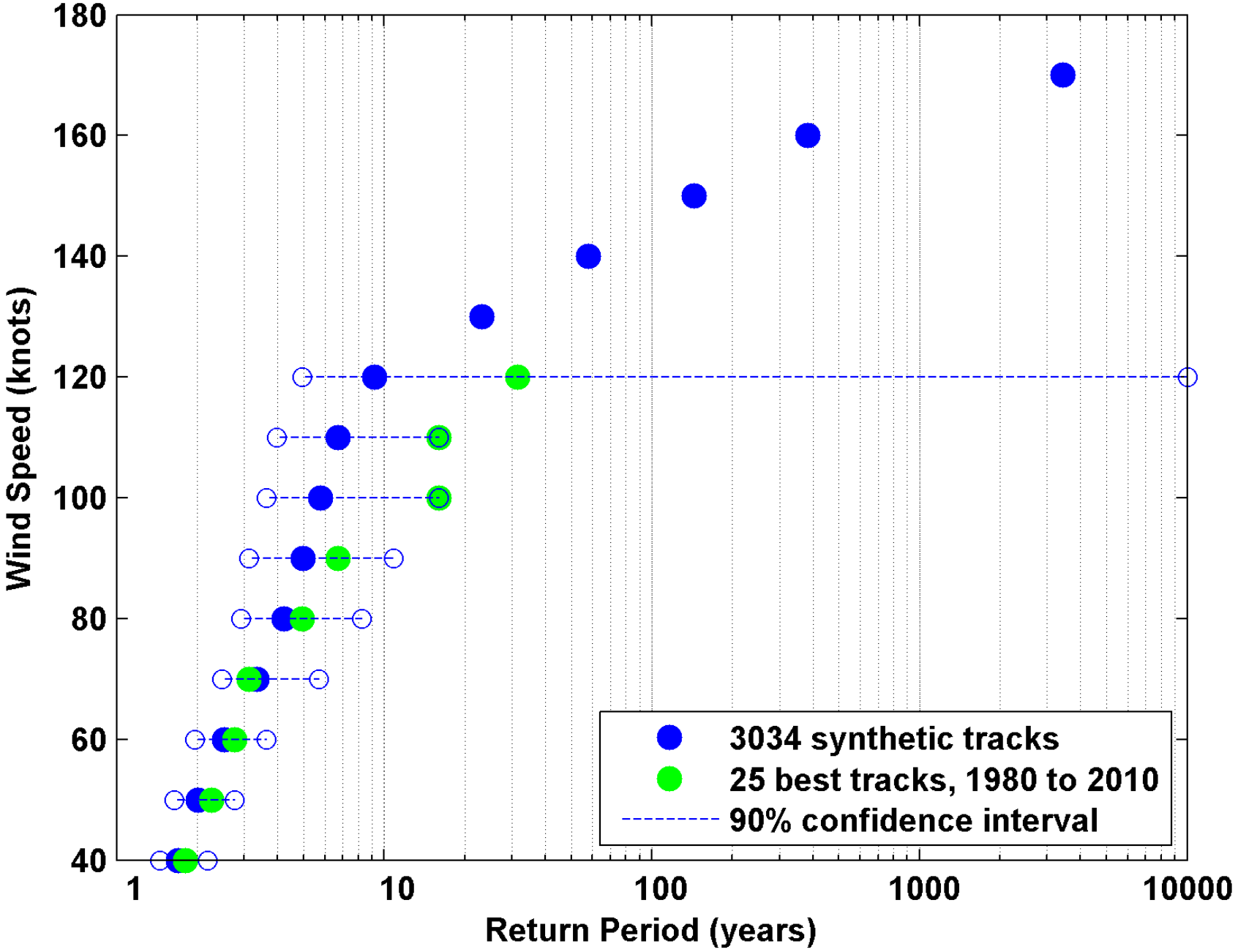
- **Step 1**: Seed each ocean basin with a very large number of weak, randomly located very weak hurricanes
- **Step 2**: Storms are assumed to move with the large scale atmospheric flow in which they are embedded
- **Step 3**: Run a detailed hurricane simulation model for each storm, and throw away those that fail to achieve at least tropical storm strength
- **Step 4:** Using the small fraction of surviving events, determine storm risk statistics

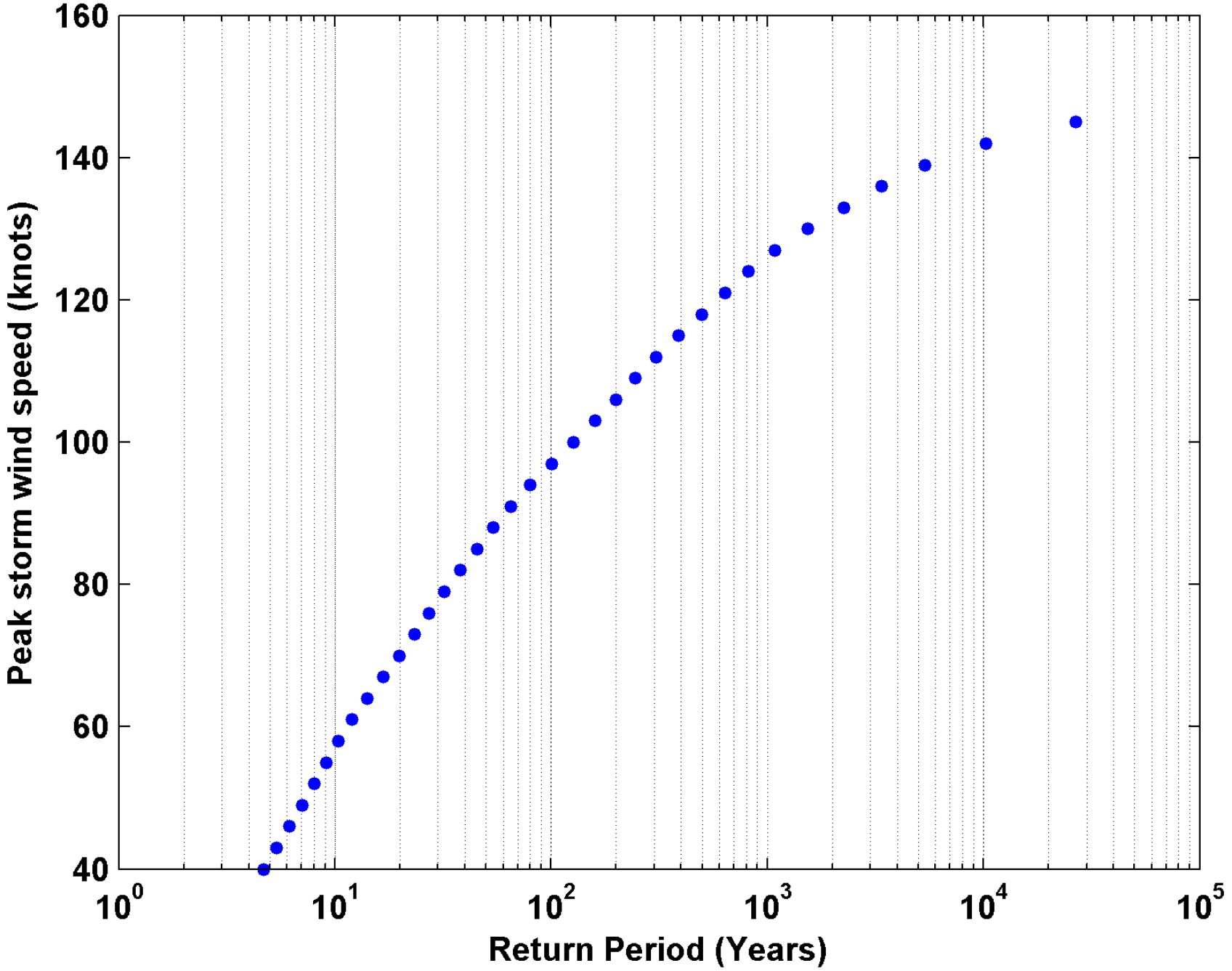
Details: Emanuel et al., *Bull. Amer. Meteor. Soc*, 2008


ERA40, 1000 Tracks
90N
70N
50N
30N
10N
10S
30S
50S
70S
40E
60E
80E
100E
120E
140E
160E
180E
160W
140W
120W
100W
80W
60W
40W
20W
0E
20E

Sample Storm Wind Swath



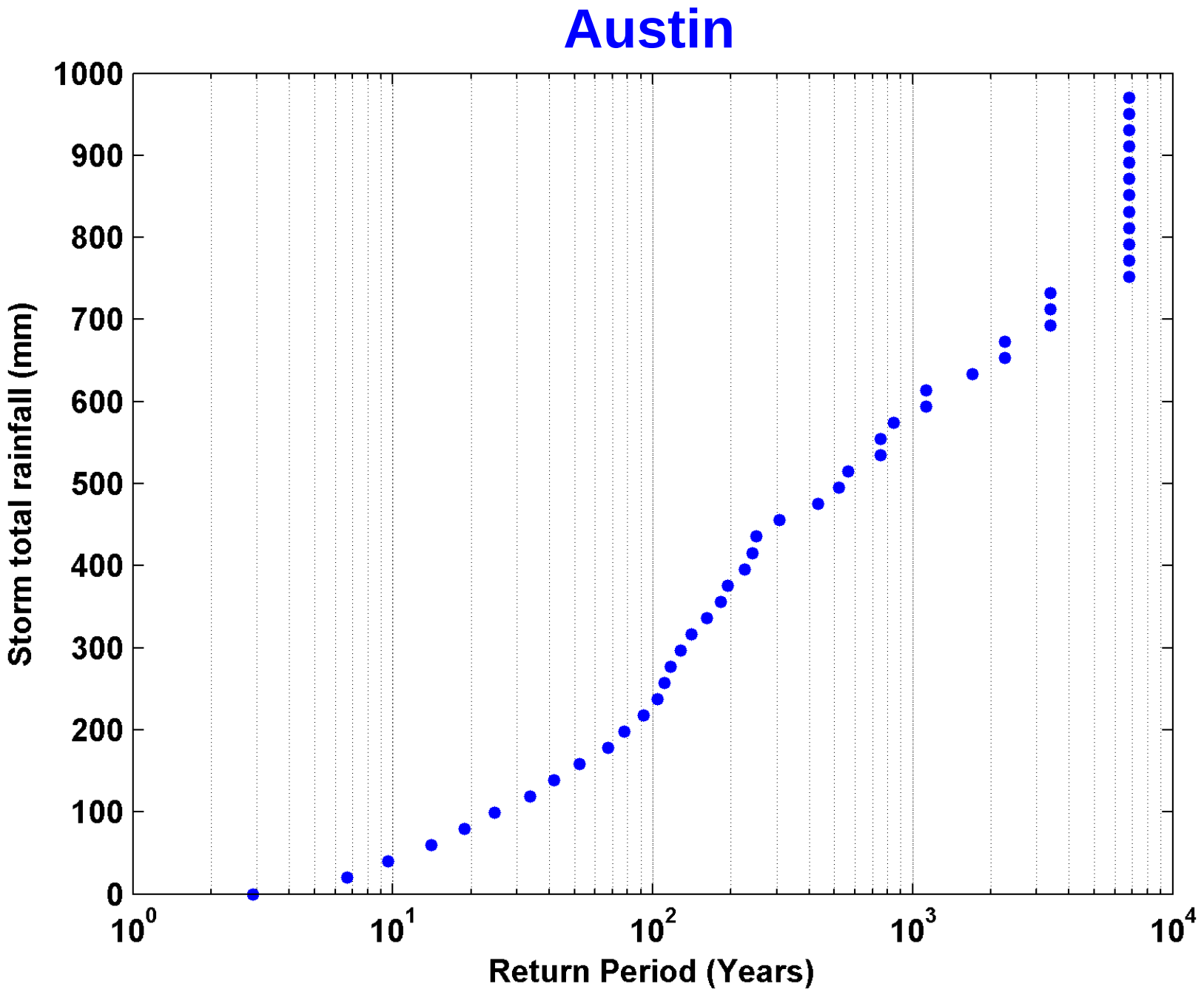

Return periods of hurricane wind speeds, Texas coast
Wind Speed (knots)
180
160
140
120
100
80
60
40
1
10
100
1000
10000
Return Period (years)
3034 synthetic tracks
25 best tracks, 1980 to 2010
90% confidence interval


Peak Wind Speed at Galveston
Peak storm wind speed (knots)
160
140
120
100
80
60
40
10^0
10^1
10^2
10^3
10^4
10^5
Return Period (Years)

Rainfall

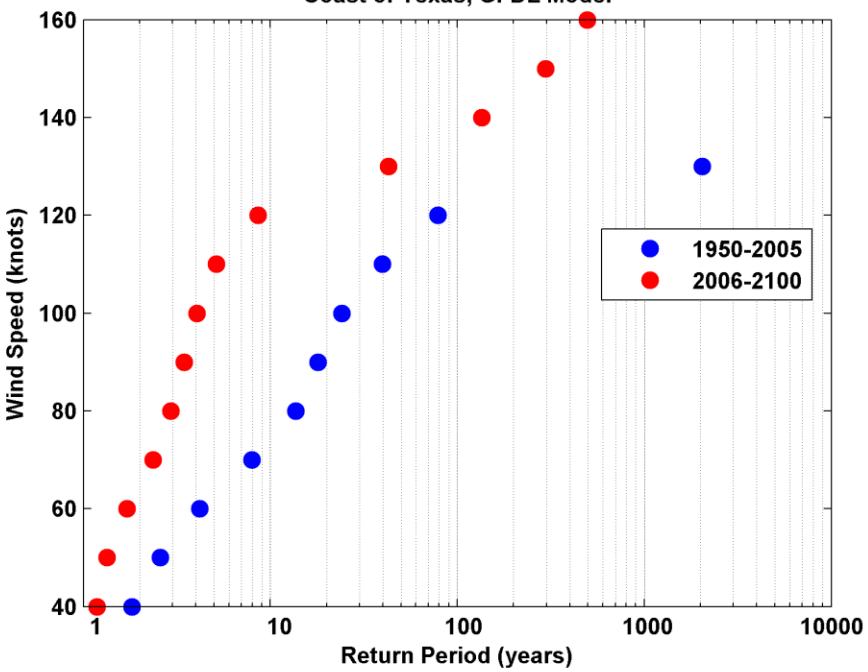
The simulation model also predicts rainfall

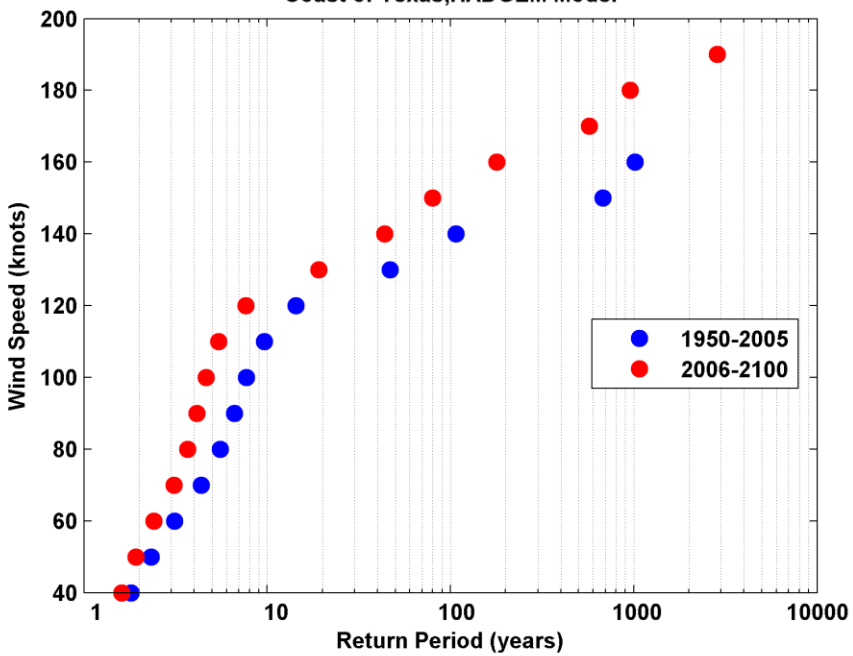
Image: NASA

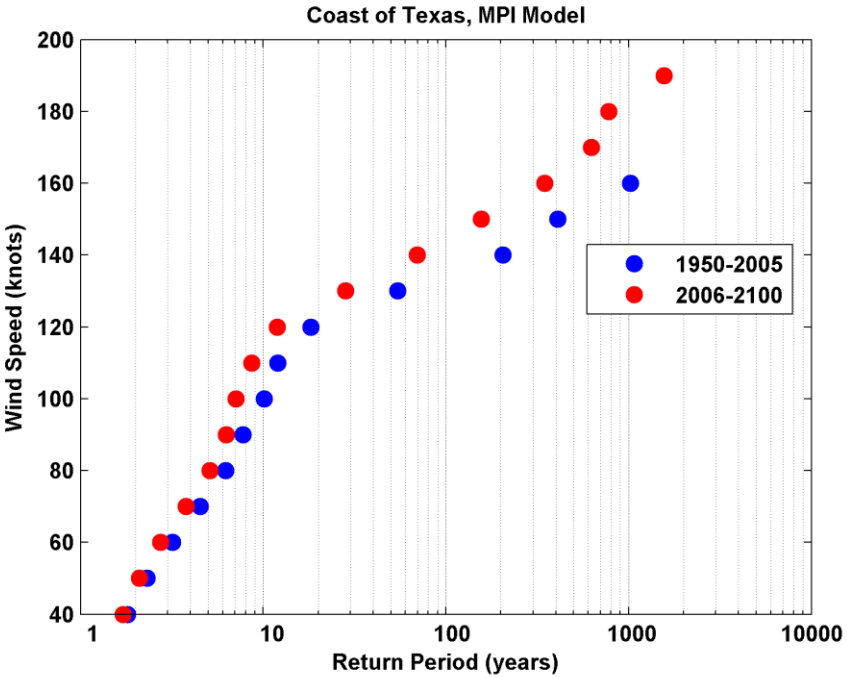

Austin
Storm total rainfall (mm)
1000
900
800
700
600
500
400
300
200
100
0
10^0
10^1
10^2
10^3
10^4
Return Period (Years)

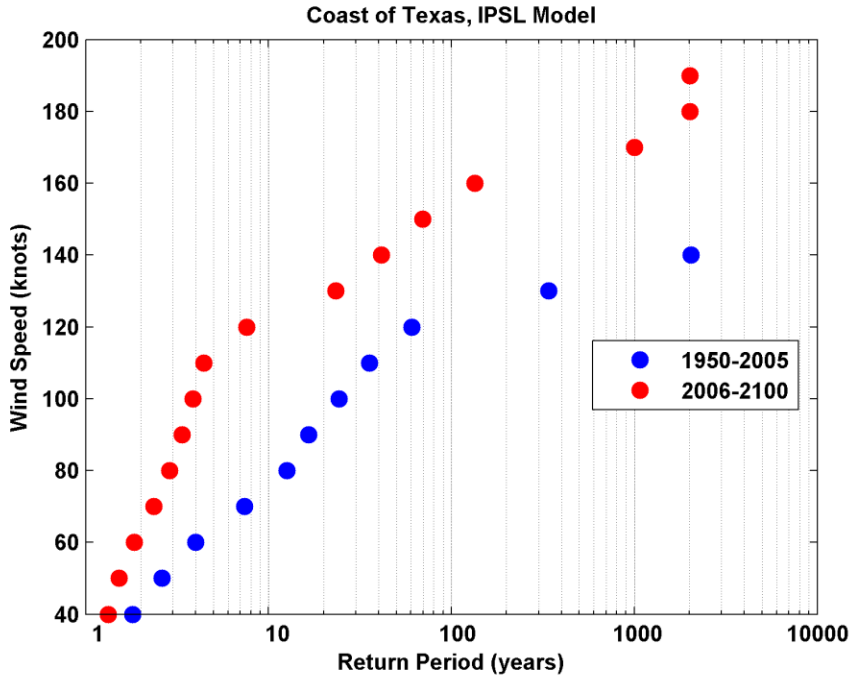
Future Texas Hurricane Risk

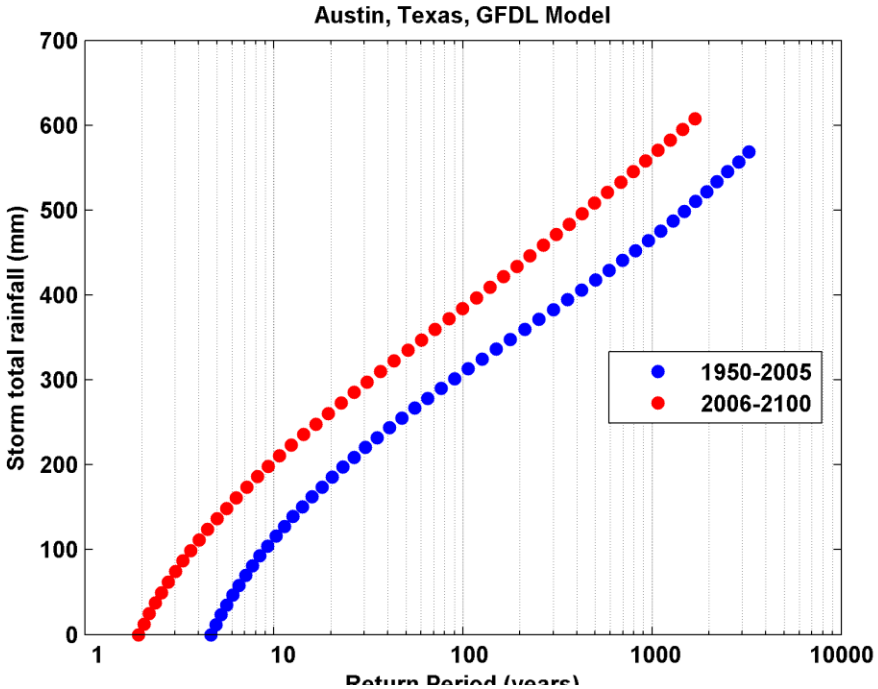
Image: NASA

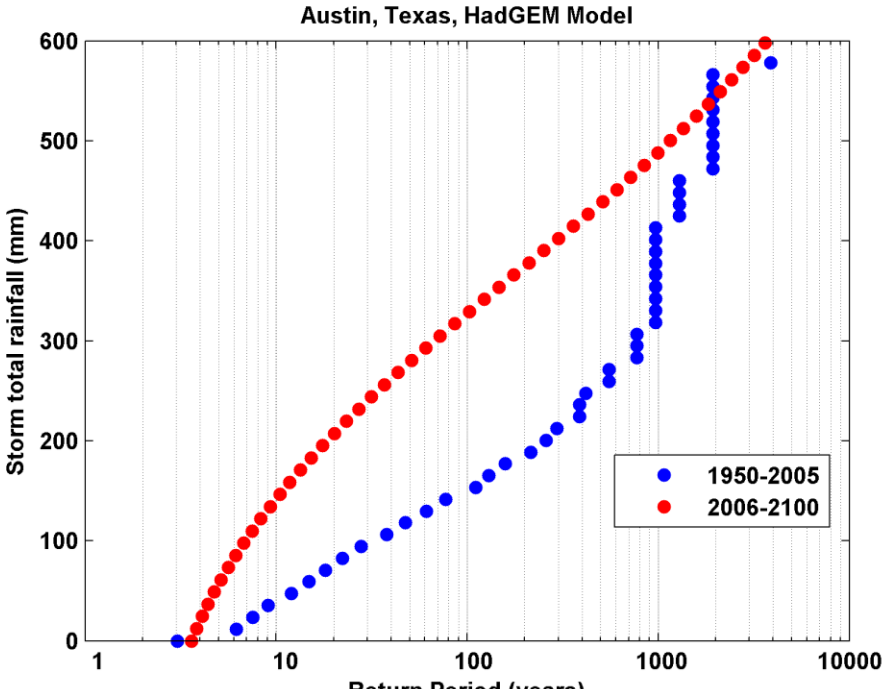

Coast of Texas, GFDL Model
Wind Speed (knots)
Return Period (years)
1950-2005
2006-2100

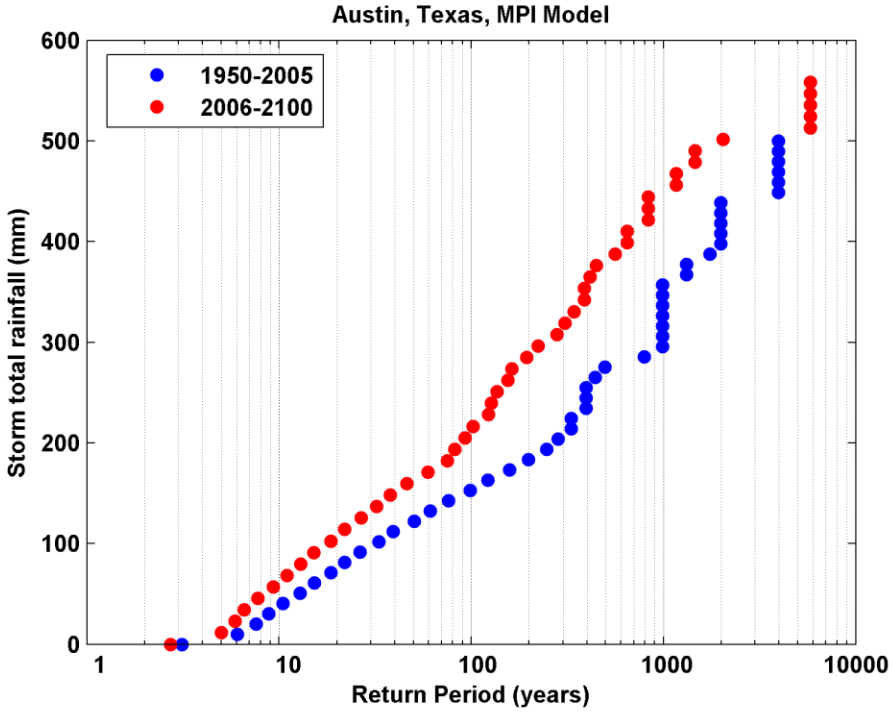

Coast of Texas,HADGEM Model
Wind Speed (knots)
Return Period (years)
1950-2005
2006-2100

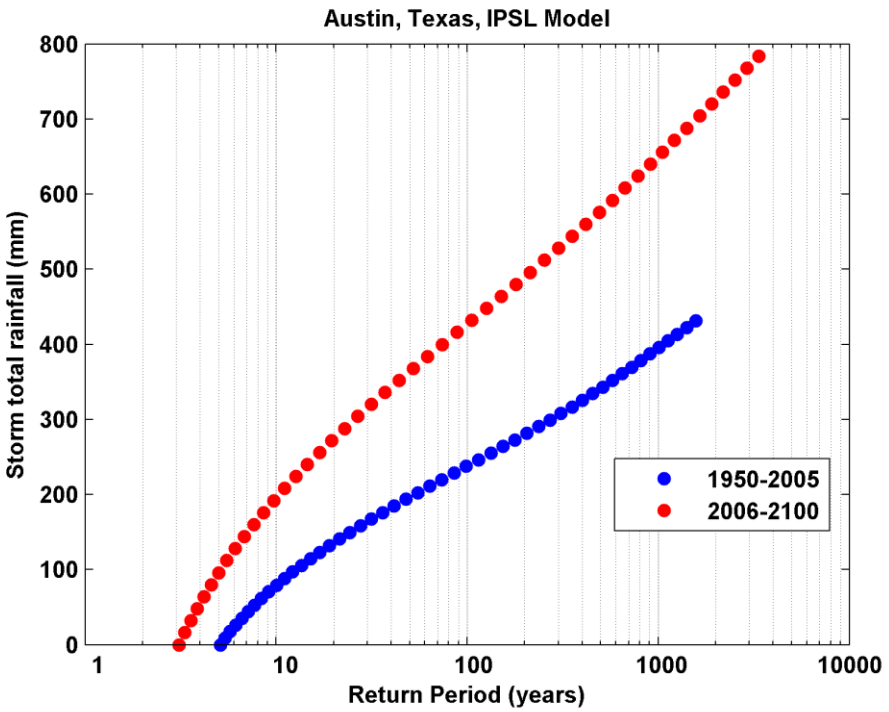

Coast of Texas, MPI Model
Wind Speed (knots)
Return Period (years)
1950-2005
2006-2100


Coast of Texas, IPSL Model
Wind Speed (knots)
Return Period (years)
1950-2005
2006-2100


Austin, Texas, GFDL Model
Storm total rainfall (mm)
Return Period (years)
1950-2005
2006-2100


Austin, Texas, HadGEM Model
Storm total rainfall (mm)
1950-2005
2006-2100


Austin, Texas, MPI Model
Storm total rainfall (mm)
Return Period (years)
1950-2005
2006-2100


Austin, Texas, IPSL Model
Storm total rainfall (mm)
Return Period (years)
1950-2005
2006-2100

Summary

- Texas has long suffered from devastating hurricanes, including the Galveston Hurricane of 1900, the worst natural disaster in U.S. history

- Texas is susceptible to all three hurricane hazards: wind, rain, and storm surge

- Global warming increases the incidence of intense, destructive hurricanes and this is reflected in model projections of increased risk of high winds, surges, and floods associated with Texas hurricanes.

Dr. Kerry Emanuel

Dr. Kerry A. Emanuel is one of the world's leading authorities on hurricanes. He is a professor in the Program in Atmospheres, Oceans, and Climate in the Department of Earth, Atmospheric, and Planetary Sciences at the Massachusetts Institute of Technology (MIT), where he received his Ph.D. degree in Meteorology. He became a member of the MIT faculty in 1981 after 3 years at the University of California, Los Angeles (UCLA). He is a fellow of the American Meteorological Society and a member of the National Research Council's Board on Atmospheric Sciences and Climate. His research focuses on tropical meteorology and climate, with a specialty in hurricane physics. His work in air-sea interaction in tropical cyclones is well regarded among the meteorological community.

Dr. Emanuel has an extensive list of publications that include two books and more than 100 peer-reviewed scientific papers. His new book, Divine Wind: The History and Science of Hurricanes, was named one of the top twenty science books of 2005 by Discover magazine. In this book, he explains how tropical climates give rise to the most powerful storms in the world. TIME magazine named Dr. Emanuel one of the 100most influential people for 2006 for his latest research, published in a recent issue of the journal Nature, which correlates the greater increasing hurricane intensity with human-induced global with human-induced global warming.