

ATM S 103

Hurricanes and Thunderstorms

Their Science and Impacts



Hurricane Gloria, 1985

Midterm 2: Wednesday May 22

- Bring a **Scantron** form
- Closed book, notes, electronics
- 30 multiple choice questions (similar to homework)
- Covers
 - Homeworks 4-6
 - Lectures from April 26 through May 15
 - Reading weeks 5-8
 - **No overlap with Midterm 1**

...SUMMARY...

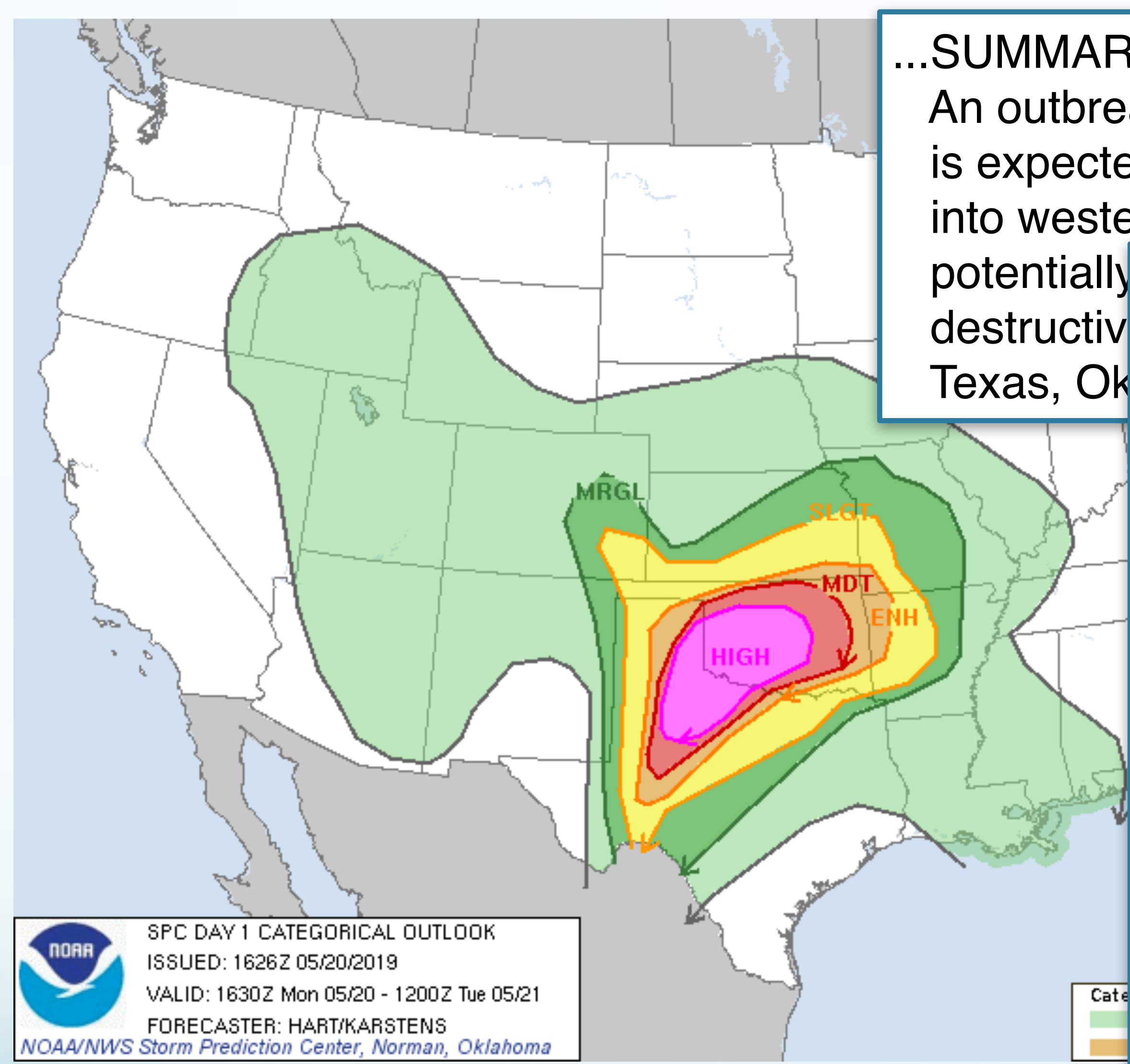
An outbreak of tornadoes, some potentially long-track and violent, is expected today into this evening over portions of northwest Texas into western and central Oklahoma. More isolated but still potentially destructive storms are expected over portions of Texas, Oklahoma, and northern Arkansas.

...Southern Plains...

A tornado outbreak is forecast to unfold this afternoon and evening across parts of northwest TX and western/central OK. Moisture continues to stream northward across the region, with dewpoints in the 70s yielding very high afternoon MLCAPE values of 3000-5000 J/kg. Meanwhile, shear profiles are also rapidly increasing as a 50-60 knot southerly low-level jet strengthens across the area. This is leading to a rare combination of extreme instability and large hodographs as depicted on forecast soundings throughout the region.

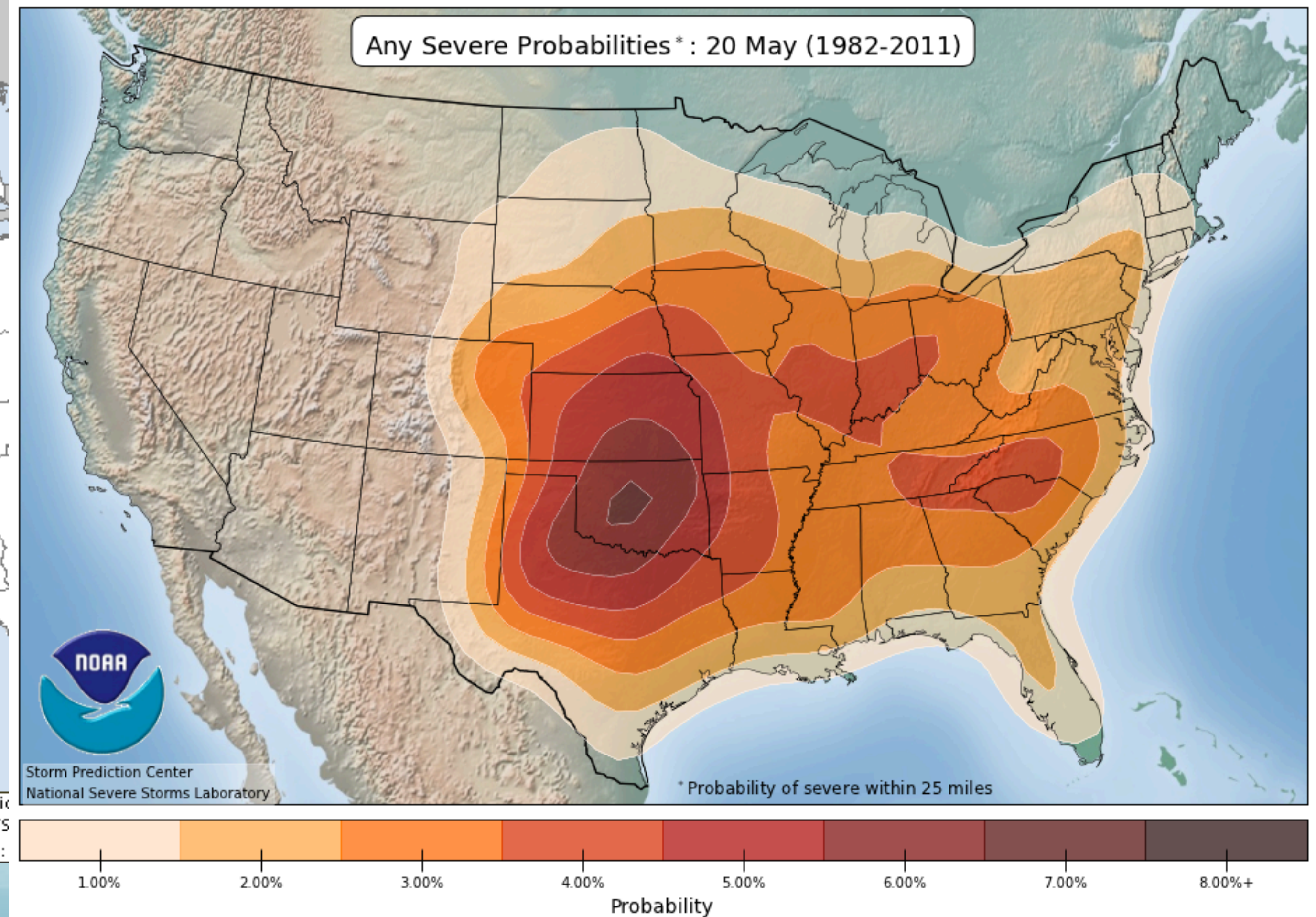
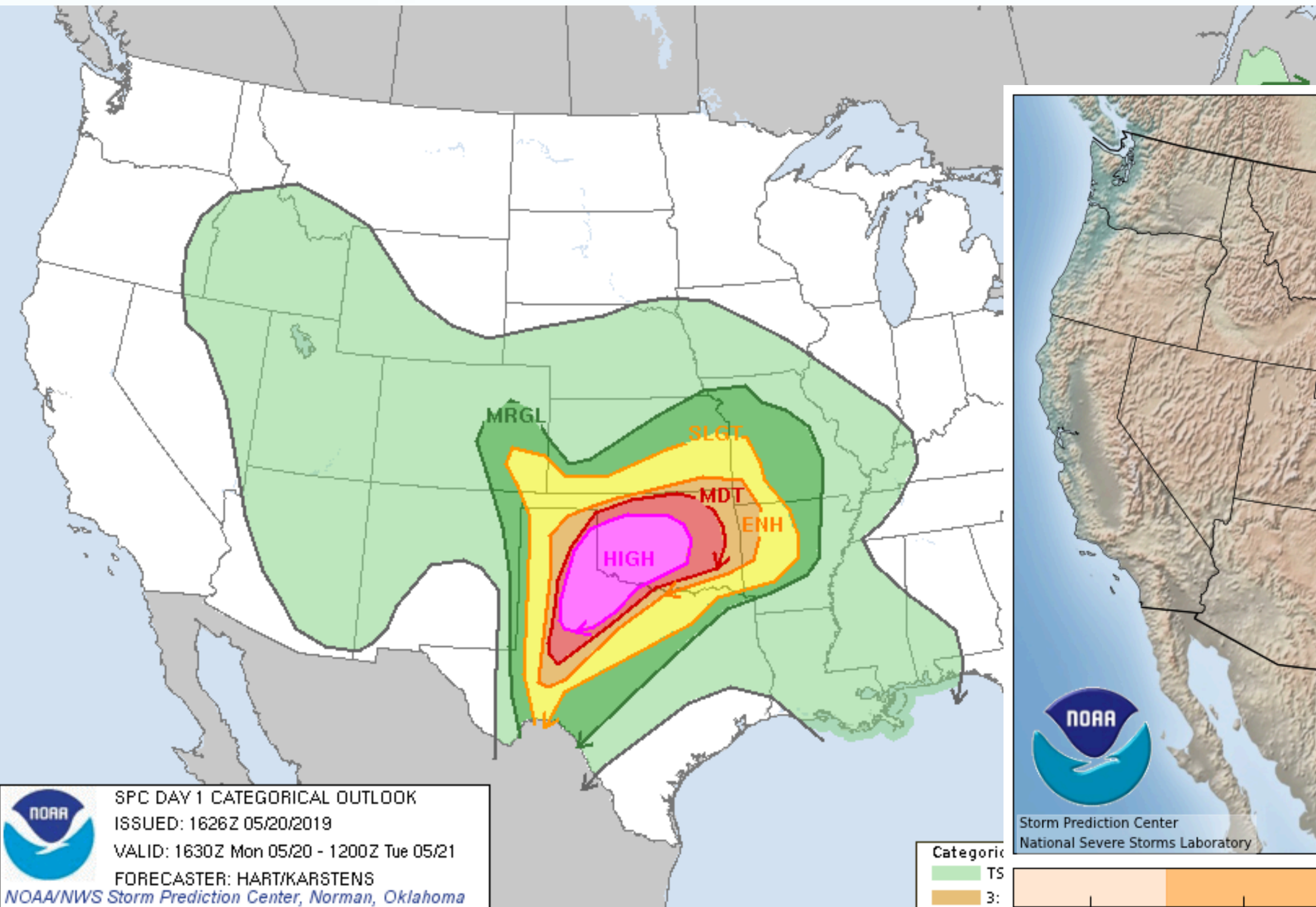
Given the weak capping inversion, strong low-level theta-e advection, and approaching large-scale forcing, all signs point to the development of numerous intense supercells this afternoon across the MDT and HIGH risk areas. Any storm that persists in this environment will pose a risk of strong tornadoes, very large hail, and damaging winds. The corridor of greatest concern, including a threat of long-track and potentially violent tornadoes, will extend from the southeast TX Panhandle into western and central Oklahoma.

Multiple rounds of severe storms are expected to affect these areas, with new storms forming this evening over west TX and spreading across north TX and much of OK overnight. These storms will maintain a risk of large hail, damaging winds, and isolated tornadoes through the night in some areas.



Day 1 Risk	Area (sq. mi.)	Area Pop.	Some Larger Population Cent
HIGH	44,967	2,006,396	Oklahoma City, OK...Norman, OK...Lawton, OK...
MODERATE	32,448	1,551,699	Tulsa, OK...Wichita Falls, TX...Broken Arrow, OK...
ENHANCED	43,768	1,909,840	Lubbock, TX...Abilene, TX...Fort Smith, AR...Ft. Worth, TX...
SLIGHT	160,622	22,537,696	Dallas, TX...Fort Worth, TX...Boston, MA...New York, NY...
MARGINAL	217,145	48,972,018	New York, NY...Philadelphia, PA...Baltimore, MD...Washington, DC...

Normal?



Tornado Sheltering Guidelines

Seek the best available refuge area **immediately** when a Tornado Warning is issued.
Your chance of surviving a tornado is excellent if you follow these guidelines.

WORST OPTIONS

Mobile homes

Vehicles

Underneath a
highway overpass

BAD OPTIONS

Large open rooms
like gymnasiums

Manufactured housing

GOOD OPTIONS

Interior room
of a well-constructed
home or building

Basement

BEST OPTIONS

Above or below ground
Tornado Storm Shelter
(NSSA/ICC 500 compliant)*

Specifically-designed
FEMA Safe Room*

Find another option

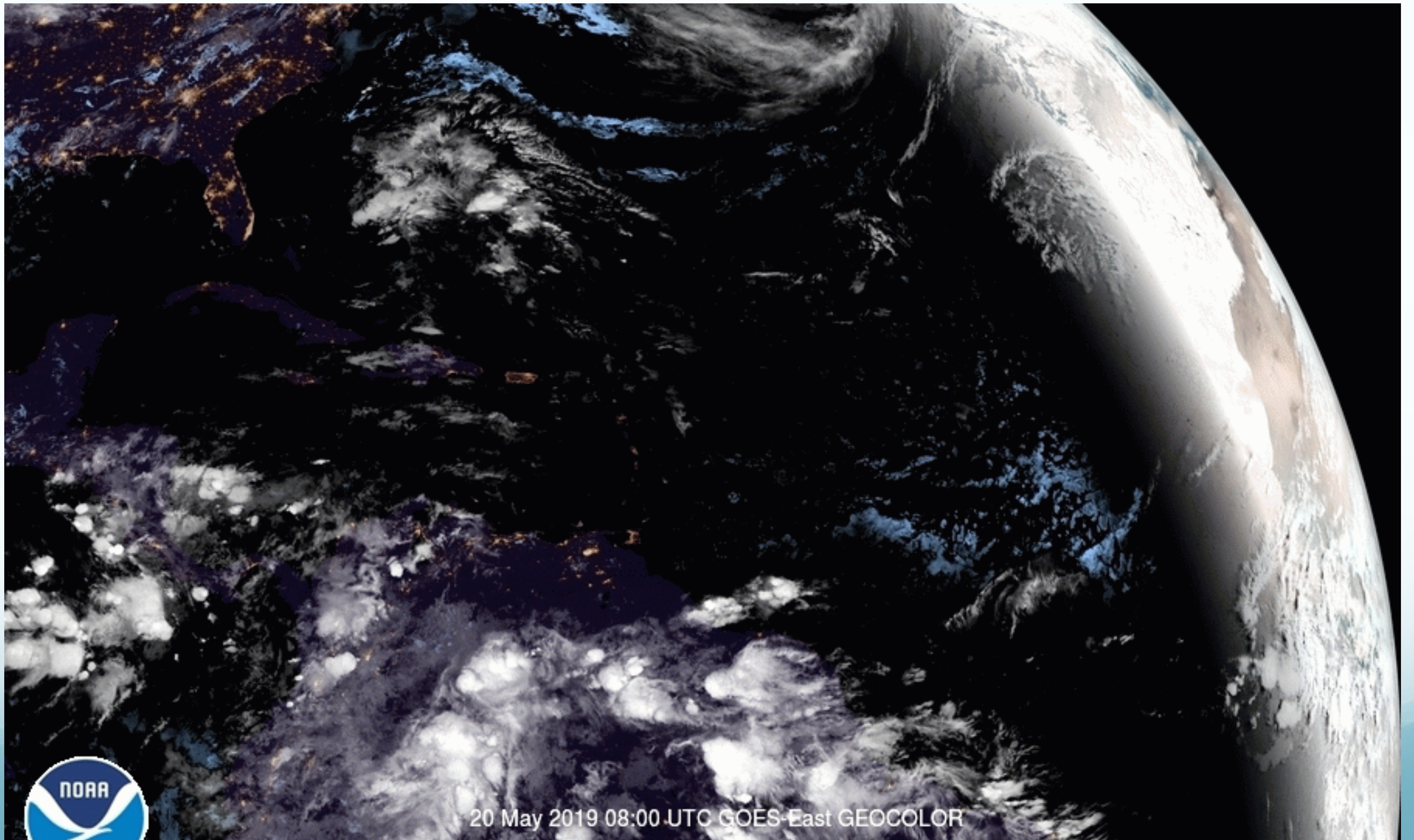


Stay in place until all clear

PHOTO: U.S. Air Force -Tech. Sgt. Bradley C. Church

*Recommended by FEMA





20 May 2019 08:00 UTC GOES-East GEOCOLOR

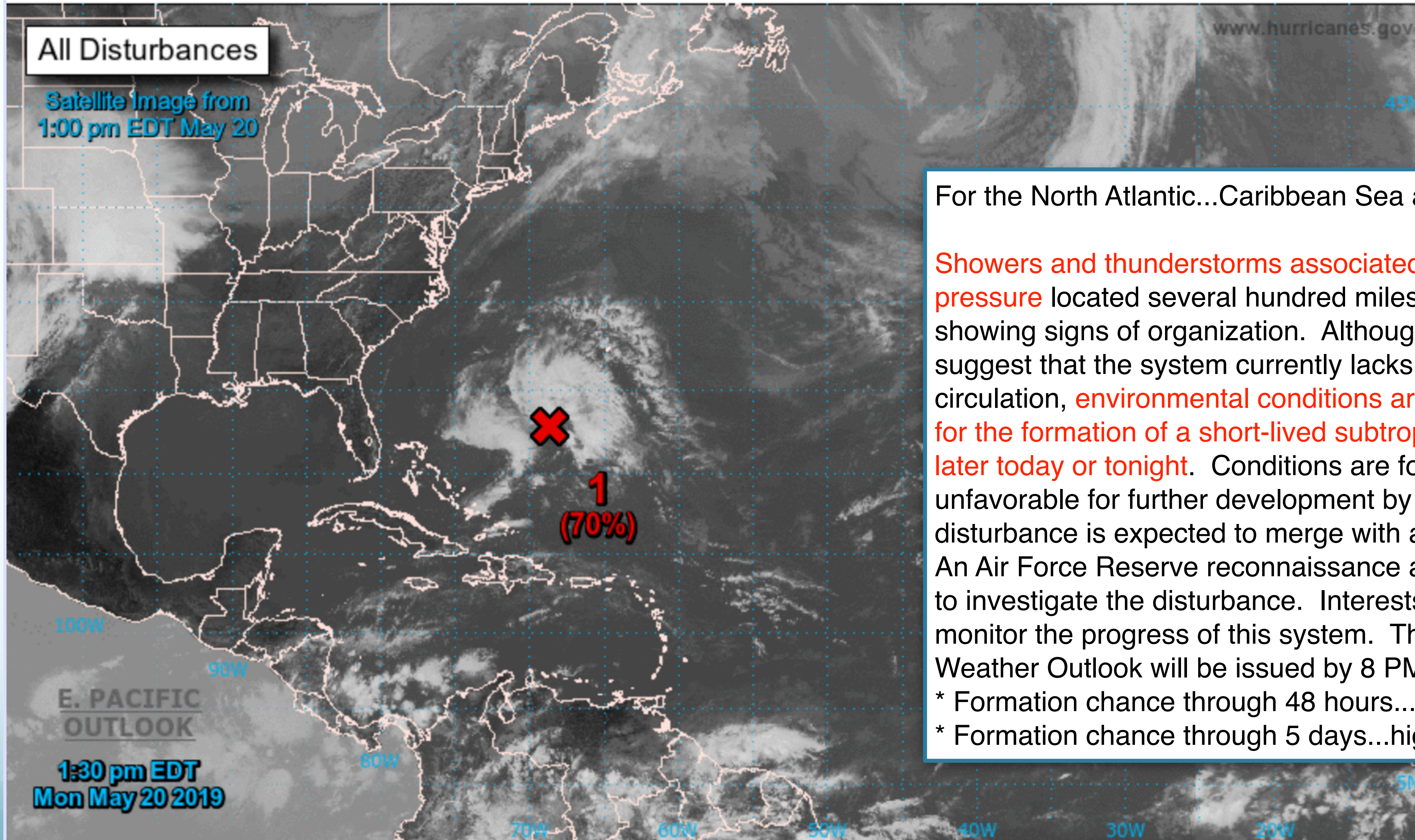


Two-Day Graphical Tropical Weather Outlook

National Hurricane Center Miami, Florida



[NHC website](http://www.hurricanes.gov)



For the North Atlantic...Caribbean Sea and the Gulf of Mexico:

Showers and thunderstorms associated with a broad area of low pressure located several hundred miles southwest of Bermuda are showing signs of organization. Although recent satellite wind data suggest that the system currently lacks a well-defined center of circulation, environmental conditions are expected to be conducive for the formation of a short-lived subtropical or tropical cyclone later today or tonight. Conditions are forecast to become unfavorable for further development by late Tuesday, and the disturbance is expected to merge with a cold front on Wednesday. An Air Force Reserve reconnaissance aircraft is currently en route to investigate the disturbance. Interests in Bermuda should monitor the progress of this system. The next Special Tropical Weather Outlook will be issued by 8 PM EDT today.

* Formation chance through 48 hours...high...70 percent.

* Formation chance through 5 days...high...70 percent.

Current Disturbances and Two-Day Cyclone Formation Chance: < 40% 40-60% > 60%

Tropical or Sub-Tropical Cyclone: Depression Storm Hurricane

Post-Tropical Cyclone or Remnants

Topics for today

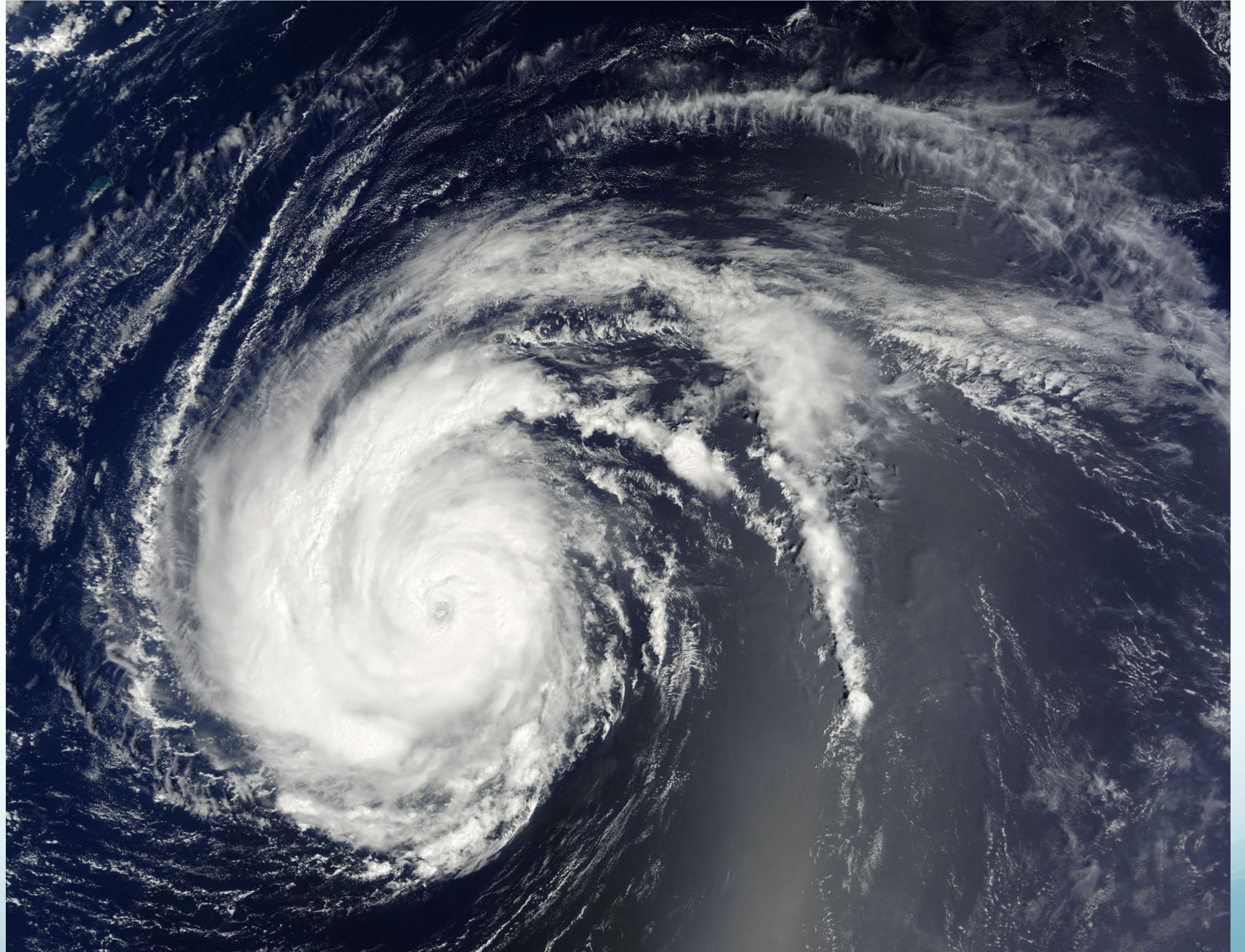
- Hurricane structure
- Storm surge
- Galveston
 - 1900 and hurricane IKE
- Satellite images
 - Visible and Infrared (IR)

Hurricane Asymmetries

Storm Relative

Hurricane Daniel
August 27, 2010

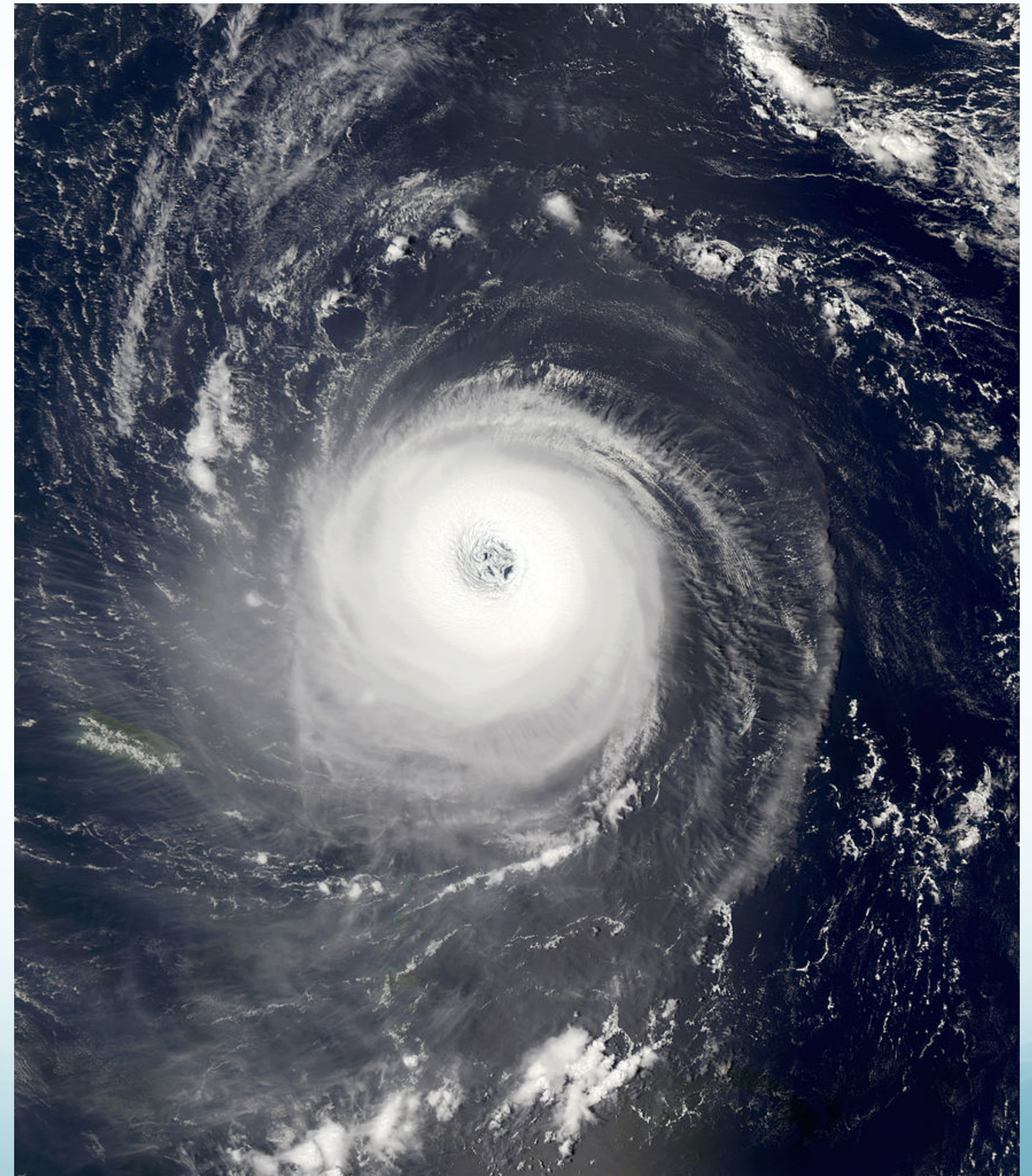
Visible in the distribution of
the spiral bands



Annular Tropical Cyclones

Hurricane Isabel
September 13, 2003

- Much more circular symmetry than the typical hurricane.
- 4% of all hurricanes
- Relatively intense storms
- Their intensity is more constant over time.

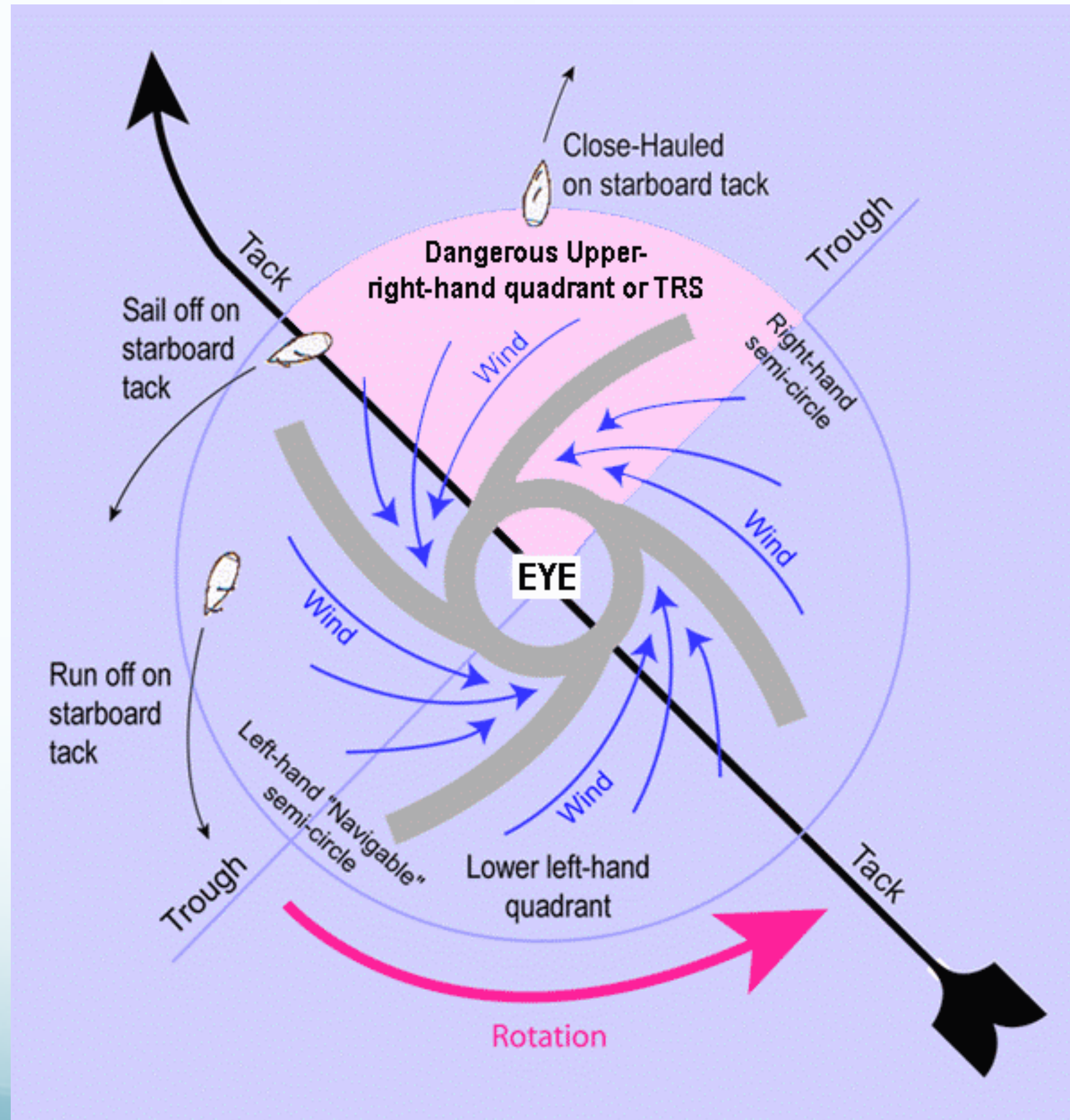


Hurricane Asymmetries

Ground Relative

- Important influence on hazards due to
 - Waves
 - Storm surge

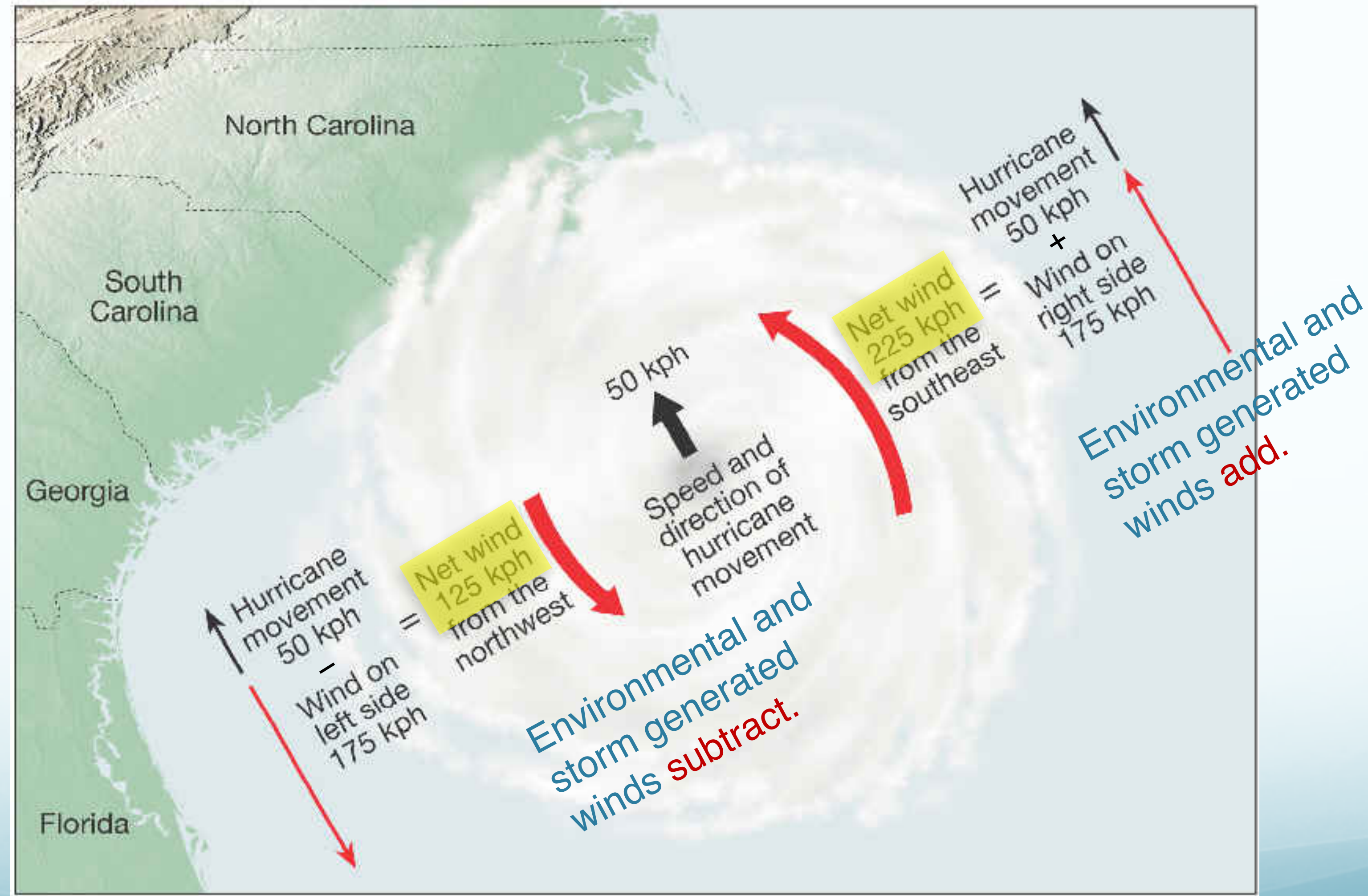
The Mariner's Viewpoint



- “Tack” should read hurricane “track”.
- Why is the right-hand side (semi-circle) worse?
- Why is the right-front quadrant particularly bad?

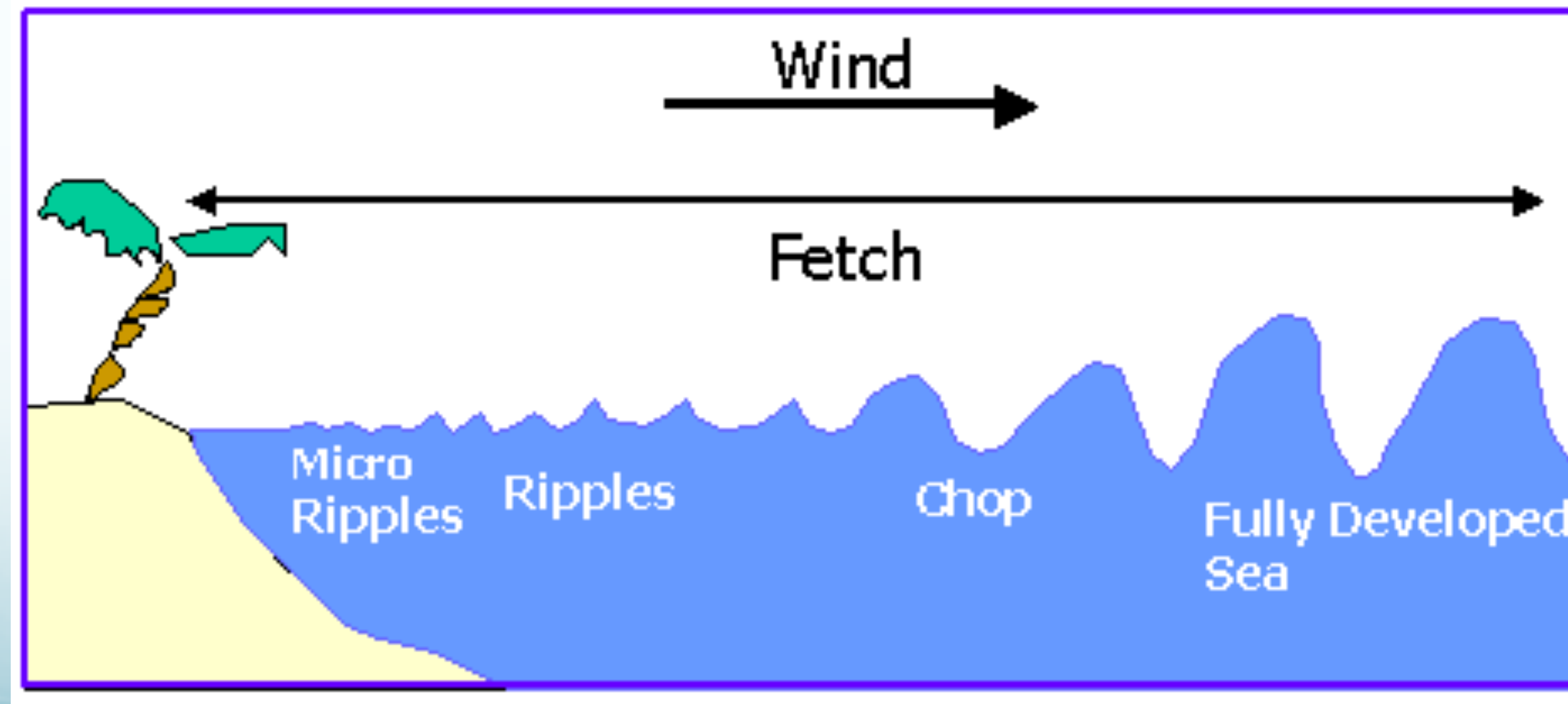
Right-hand side gets higher winds.

Example: environmental winds are 50 kph (31 mph);
hurricane induced circular wind is 175 kph (109 mph).

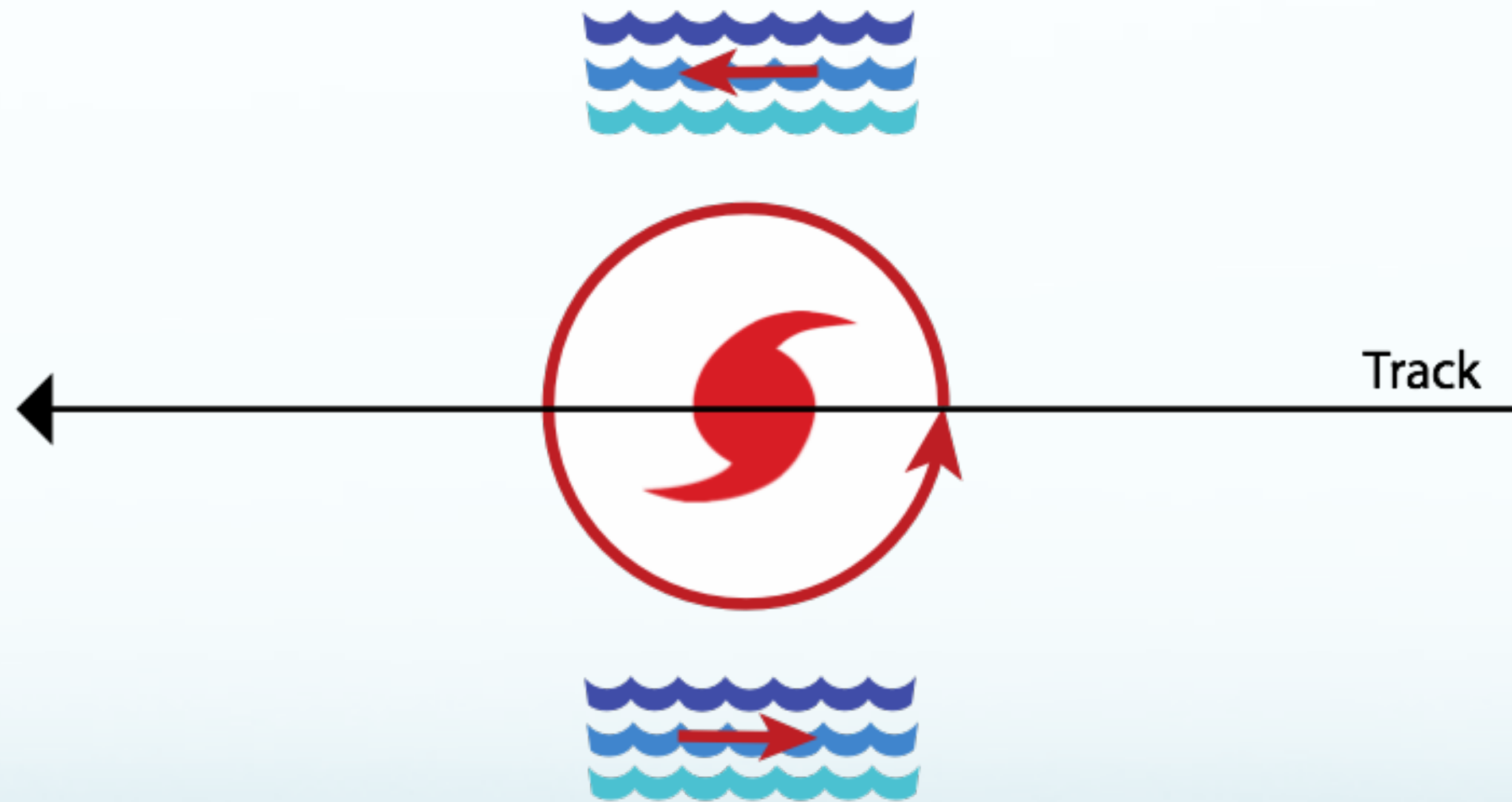


Higher Waves in the Right Front Quadrant – Why?

- Waves are generated by wind blowing across the sea surface.
 1. The **stronger** the **winds**, the bigger the waves.
 2. The **more time** the waves are **exposed to the wind**, the larger they get.
(Why more time?)

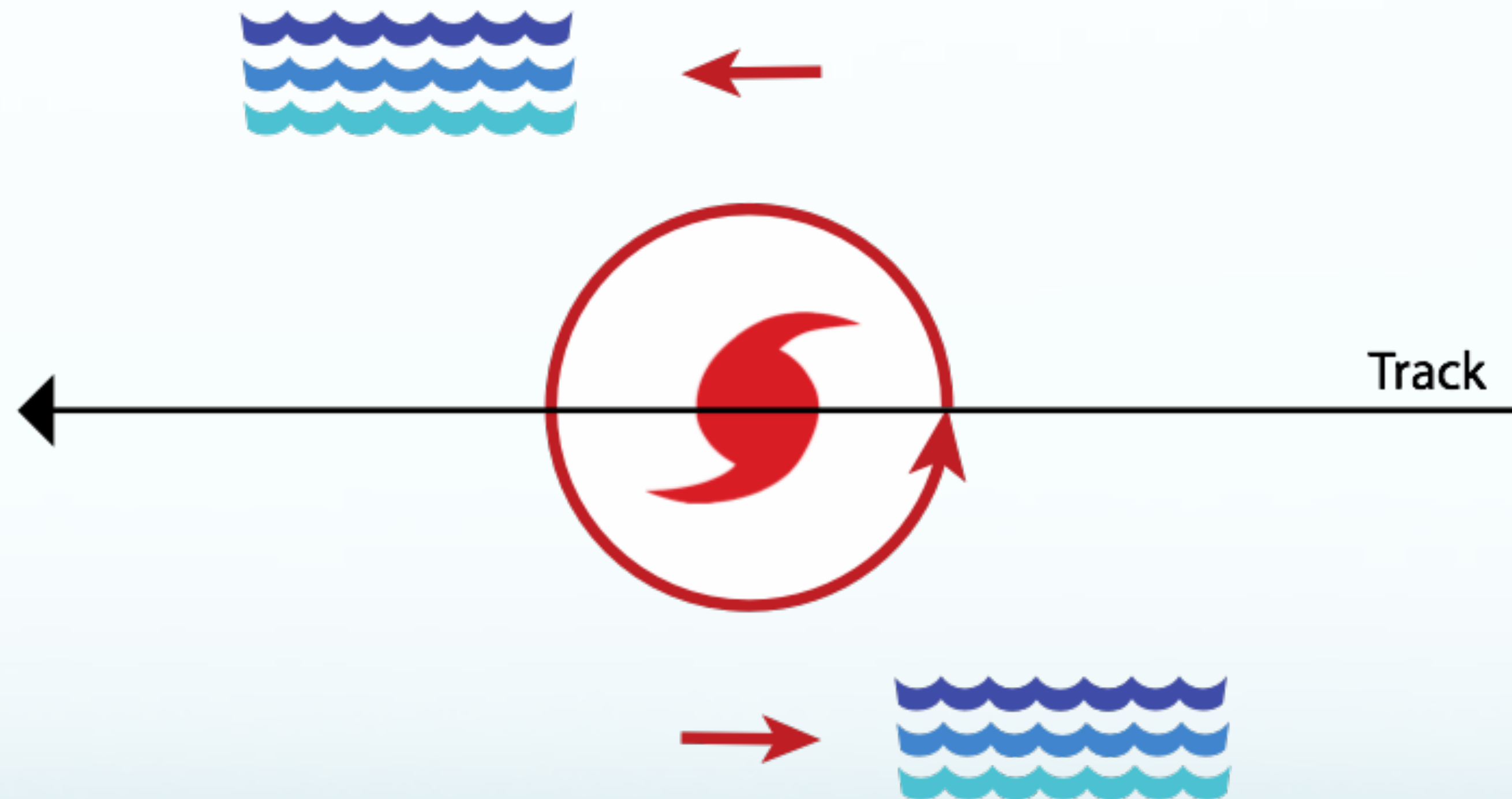


Hurricane Winds Generating Waves



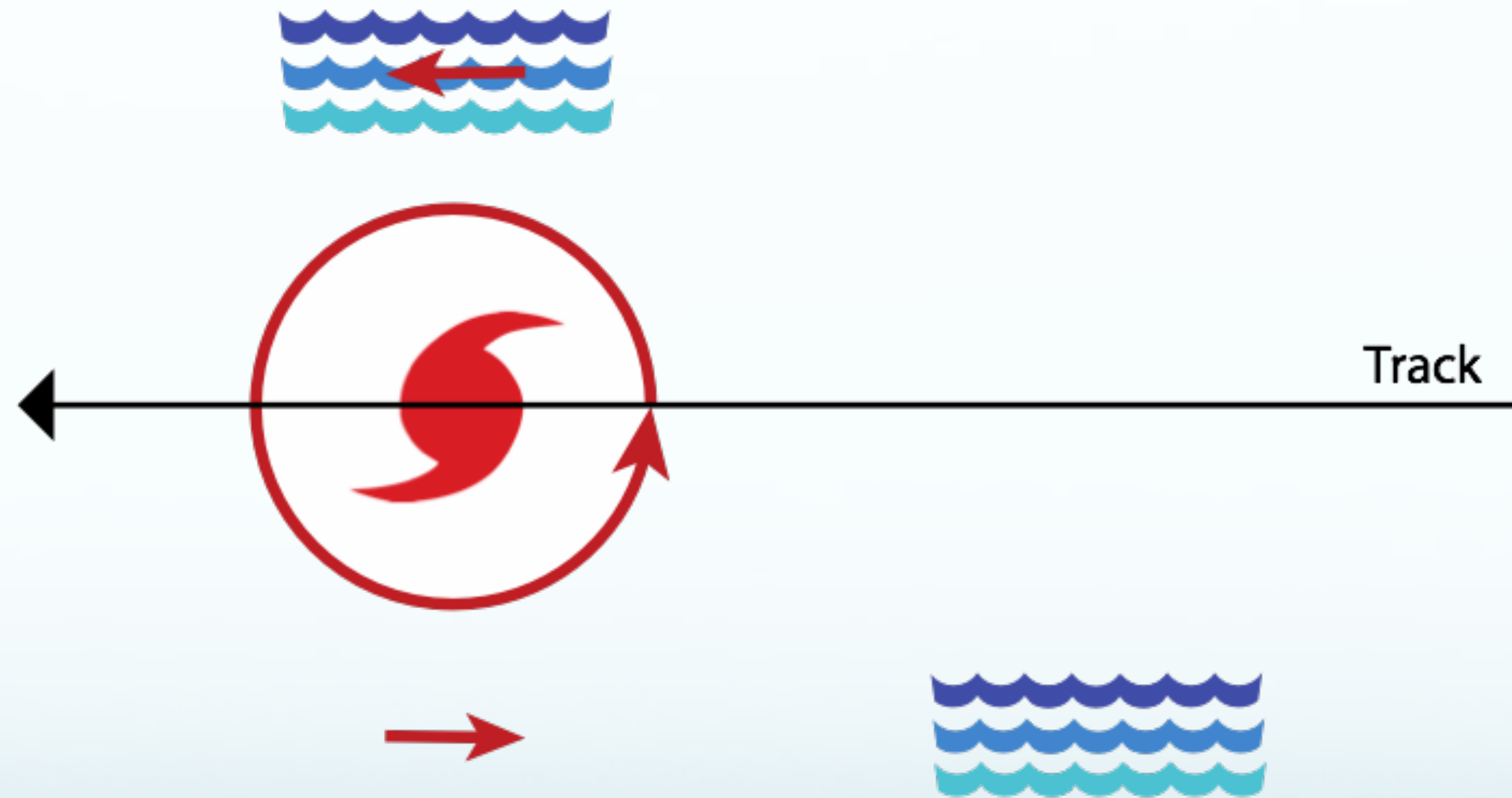
Waves propagate away from region of generation.

Hurricane motion is frozen.

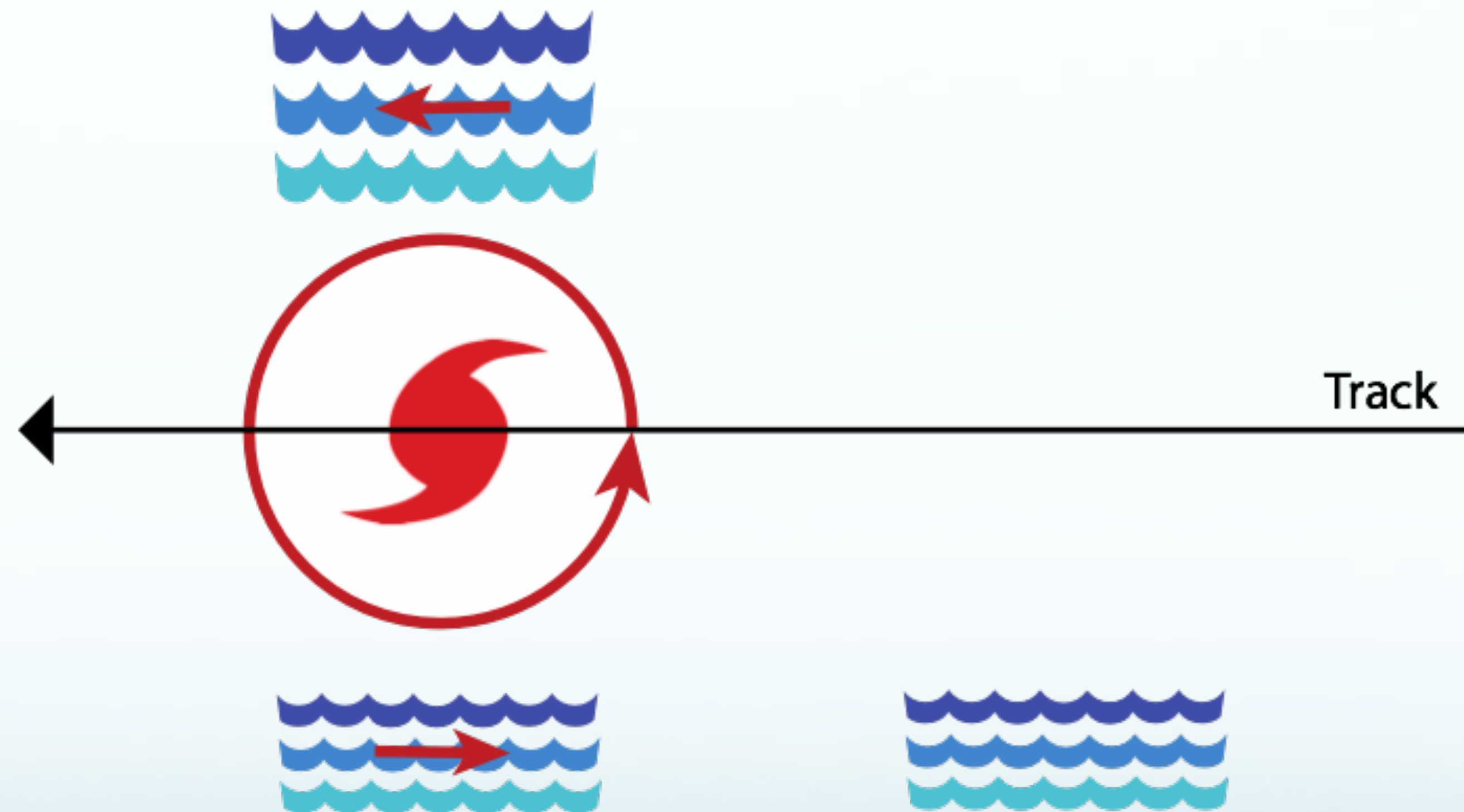


Unfreeze the Hurricane

Account for hurricane motion as well a wave propagation.
(Suppose it moves at the same speed as the waves.)

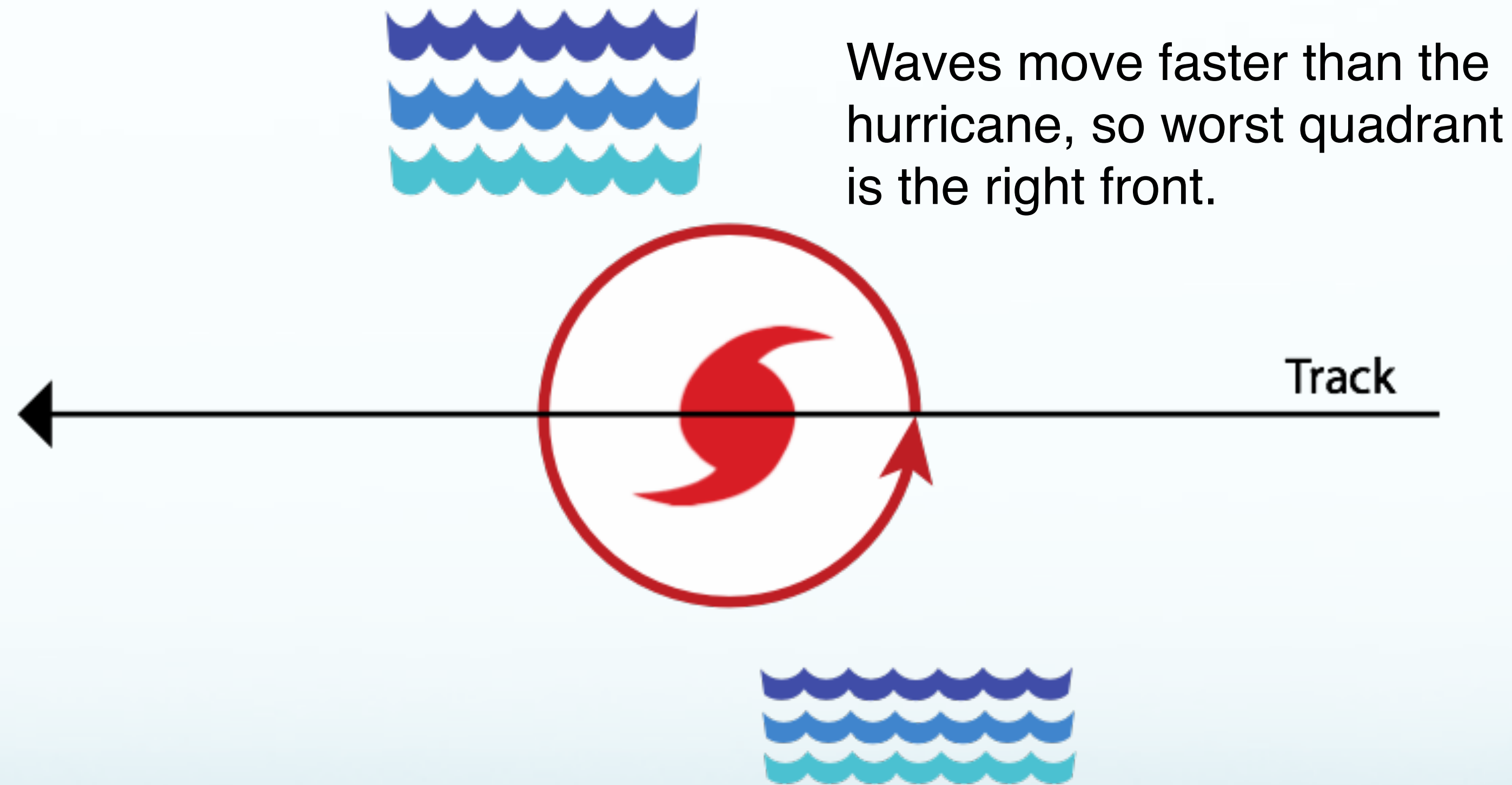


Older right-side waves continue to be exposed to strong winds; they strengthen.
New weaker waves are generated on the left side.



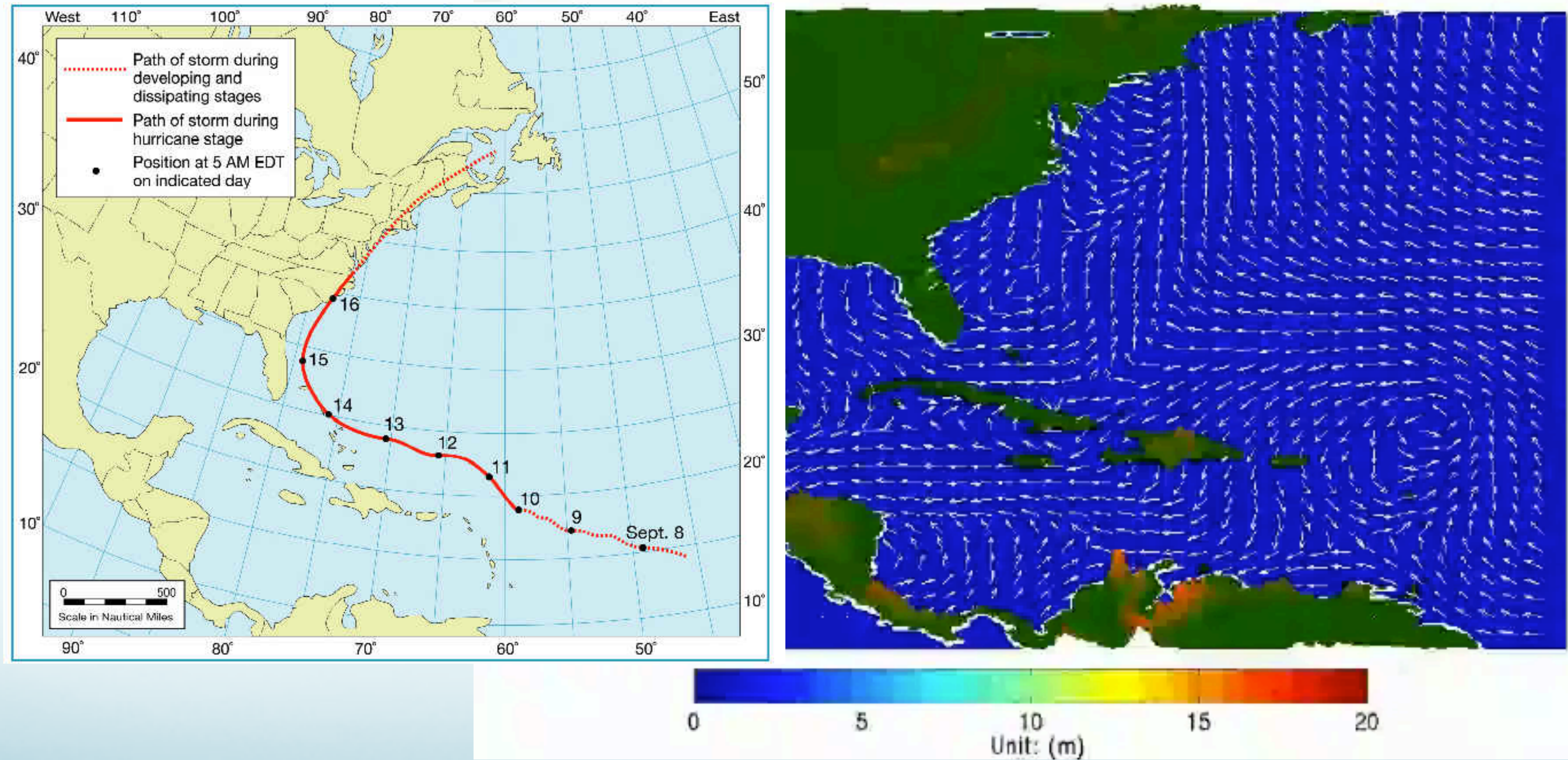
Each set of waves is exposed to high winds longer on the right side of the storm than on the left side.

These larger waves propagate into the right-front quadrant.



Hurricane Floyd: Simulated Wave Height

Significant Wave Height / Wave Direction 19990911 00Z (Hurricane Floyd)



W

Which tropical-cyclone quadrant is most dangerous in the southern hemisphere?

Right front

Left front

Right rear

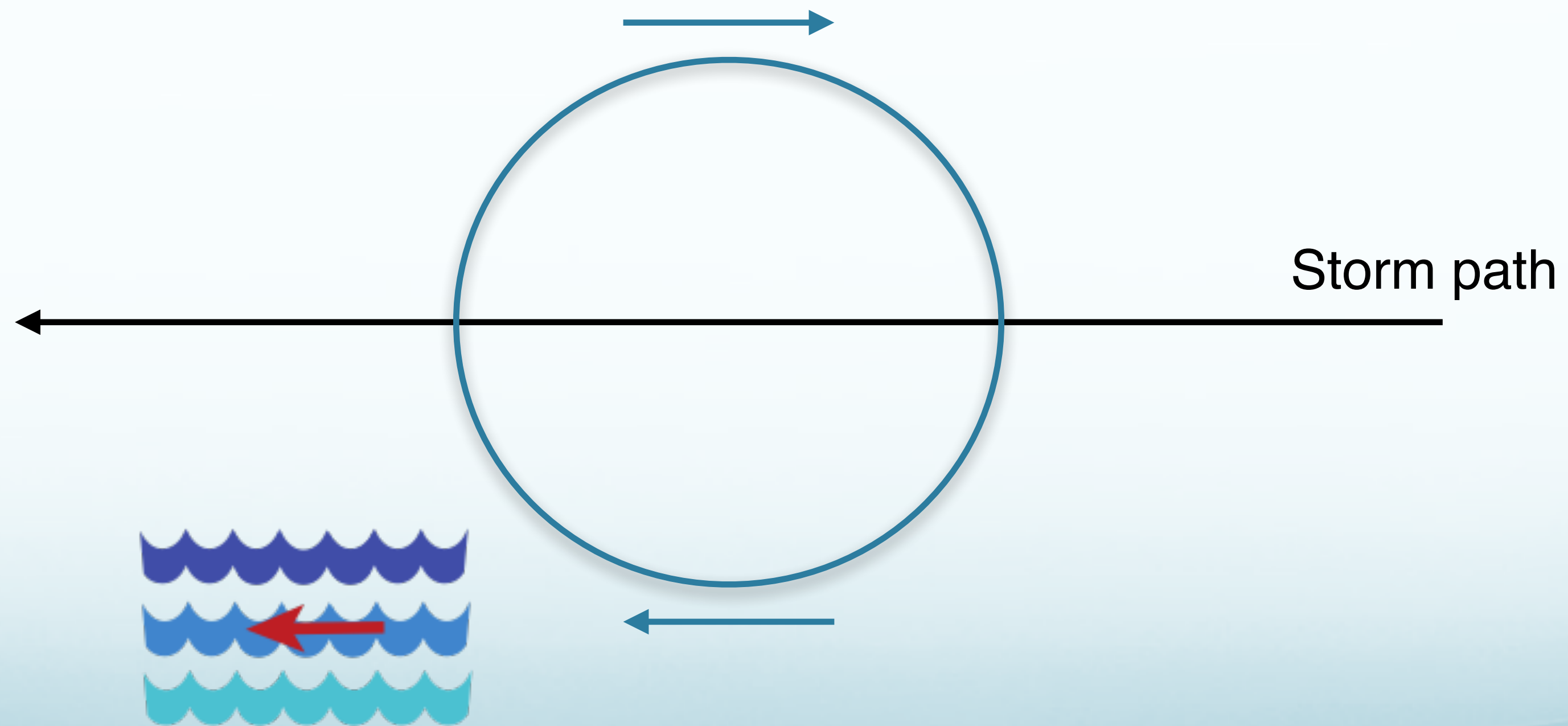
Left rear

Start the presentation to see live content. Still no live content? Install the app or get help at [PollEv.com/app](https://pollev.com/app)

Total Results

Answer

- Because cyclones spin the opposite direction in the SH, the most dangerous quadrant is the left front.



Hurricane-caused fatalities

- Most of them are due to
 - High winds?
 - Water (flooding, storm surge)?

Hurricane-caused fatalities

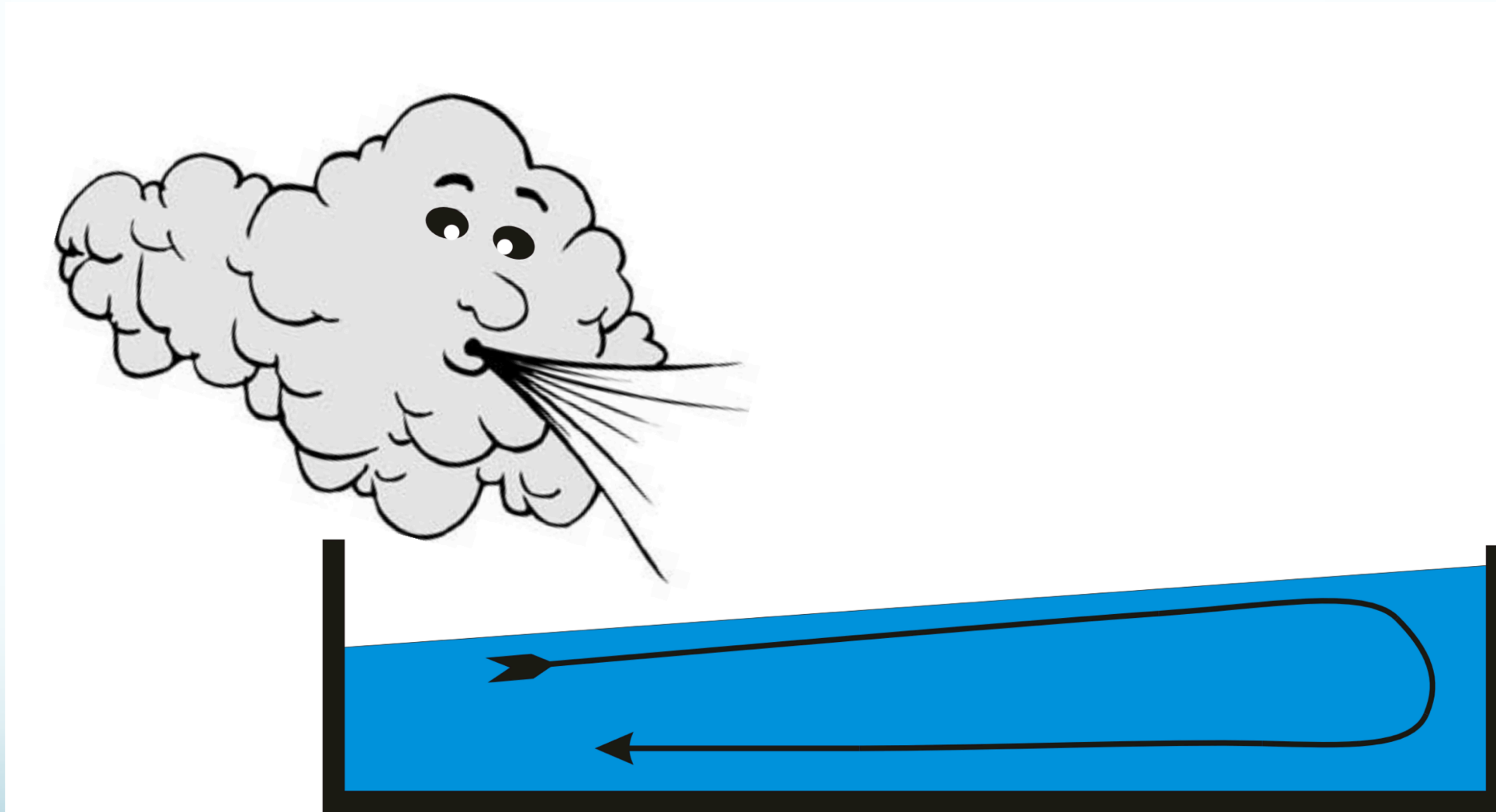
- Most of them are due to
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Storm Surge

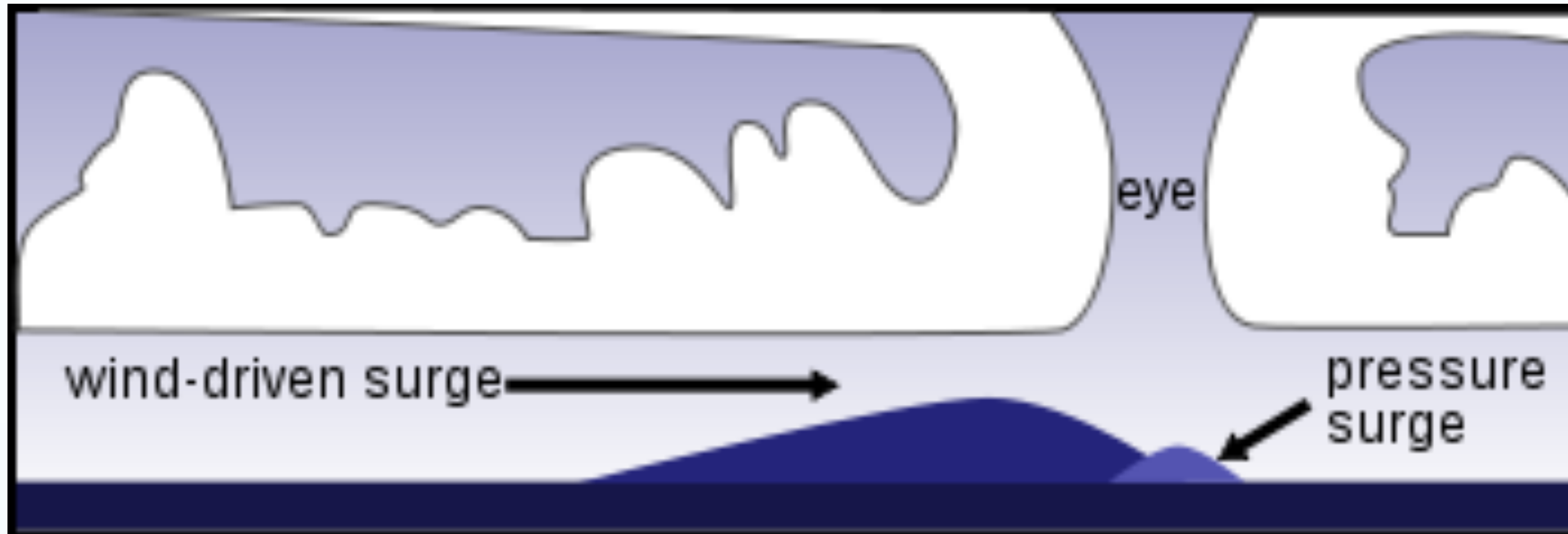


Storm surge damage to Texas coast after Hurricane Ike. Photo: NOAA.

Produced primarily by wind blowing water
against a shore



Secondarily by the local drop in pressure
near the eye.



Pressure contribution typically just 5% of total surge.

Storm Surge Influenced by

- Wind speed (major factor)
- Drop in atmospheric pressure (minor factor)
- Shape of the sea floor / beach slope
- Path of the hurricane relative to the coast.
 - Is the storm approaching head-on or almost parallel to the coast.

**A hurricane is making landfall in the northern hemisphere,
W heading directly perpendicular to the coast. The most damage will
tend to occur**

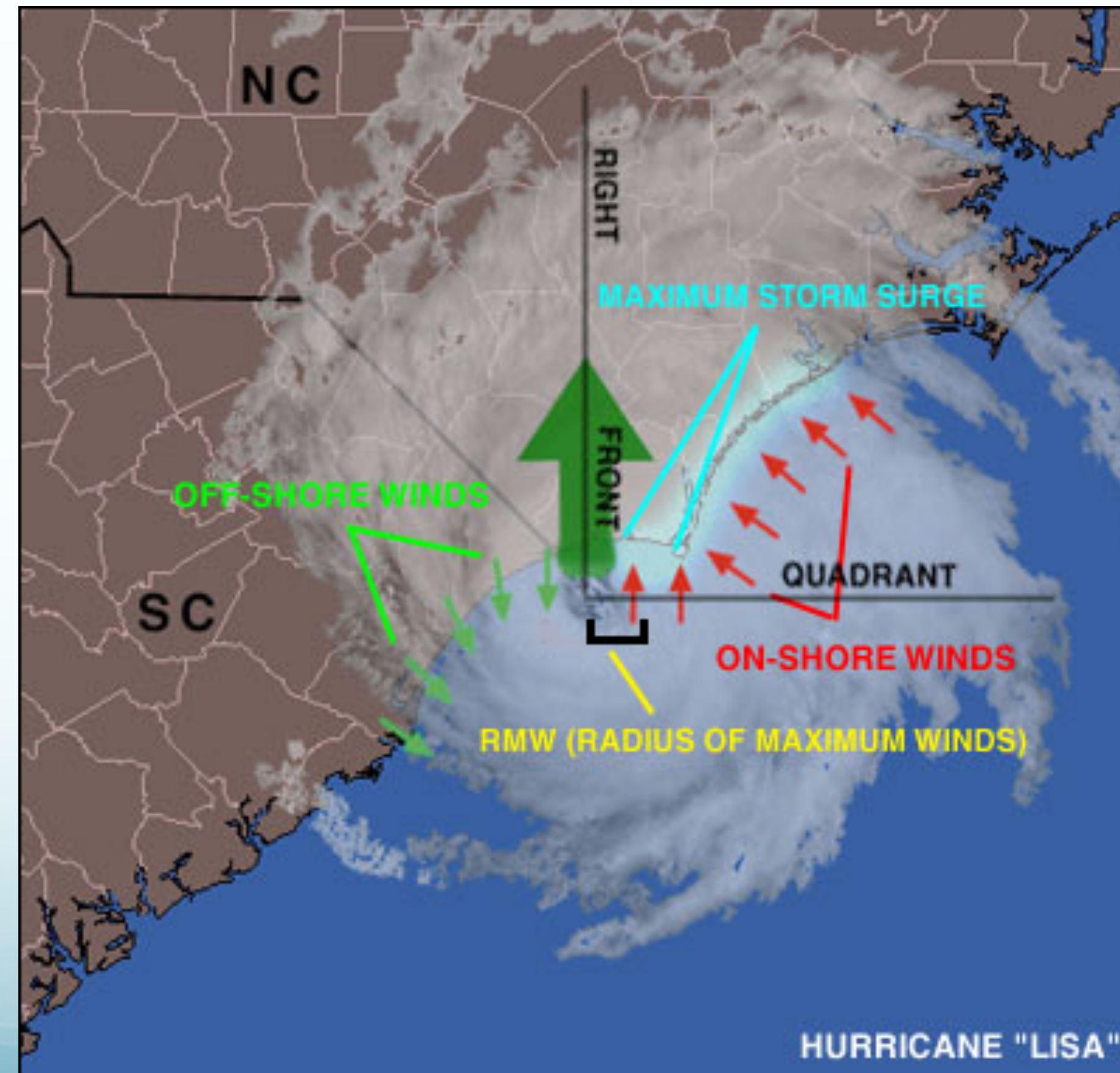
Just outside the eye on the
left side of the track

Exactly where the center
of the eye hits land

Just outside the eye on the
right side of the track

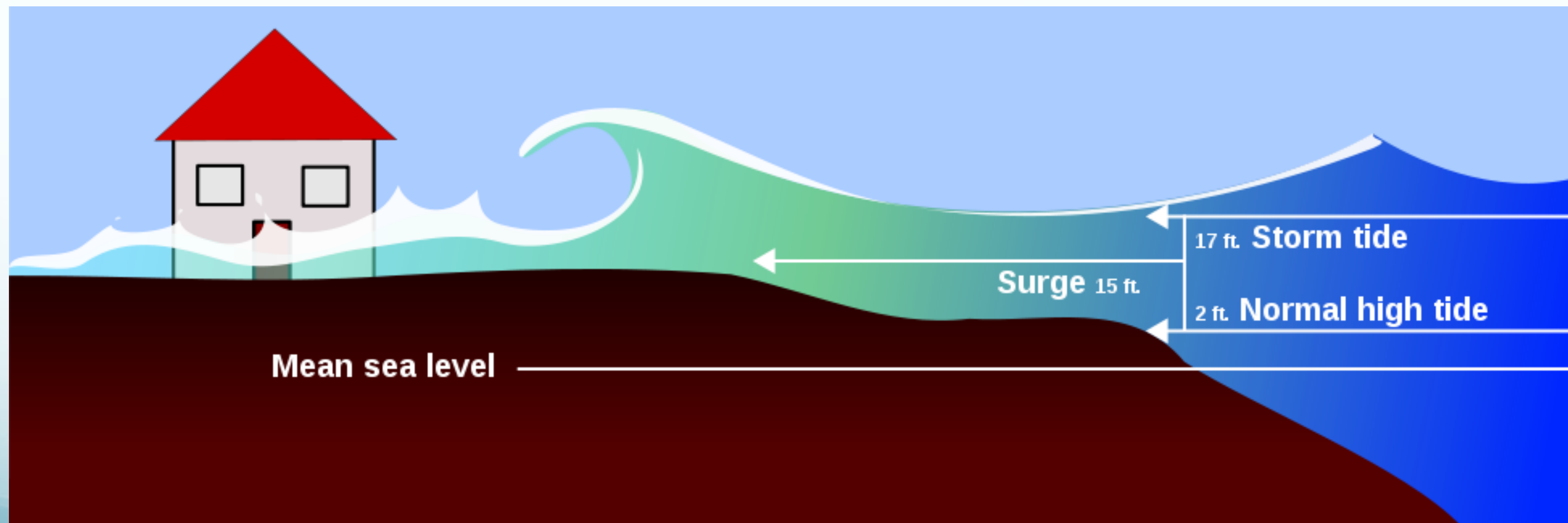
Answer

- The most damage will occur just outside the eye to the right of the track.



Factors Determining the Storm Tide

- Astronomical tide (2 high tides, 2 low tides per day)
- Storm surge (generated by the hurricane)
- (High waves ride on top of the storm tide.)



Storm Surge Vulnerability Facts

During a severe surge: [The Weather Channel](#)

From 1990-2008, population density increased by 32% in Gulf coastal counties, 17% in Atlantic coastal counties, and 16% in Hawaii (U.S. Census Bureau 2010)

Much of the United States' densely populated Atlantic and Gulf Coast coastlines lie less than 10 feet above mean sea level

Over half of the Nation's economic productivity is located within coastal zones

72% of ports, 27% of major roads, and 9% of rail lines within the Gulf Coast region are at or below 4 ft elevation (CCSP, SAP 4-7)

A storm surge of 23 ft has the ability to inundate 67% of interstates, 57% of arterials, almost half of rail miles, 29 airports, and virtually all ports in the Gulf Coast area (CCSP SAP 4-7)

Record High Storm Surge

- **43-48'** Bathurst Bay Cyclone (Australia) March 5, 1899
- Constable J. M. Kenny camped on a ridge 40 feet above sea level and 1/2 mile inland. A wave left him waist-deep in water.
- On nearby Flinders Island, fish and dolphins were found on top of 49 foot cliffs.
- Nevertheless, this was probably mostly due to storm waves, not the surge (or storm tide) per se.
 - Sea floor slopes steeply away from the coast.
 - Great Barrier Reef roughly 20 miles from the shore.

Other Extreme Storm Surges

- 40-44' Great Backerganj Cyclone of 1876.
- 34.8' Great Bhola Cyclone of 1970, during one of the highest high tides of the year
- Bangladesh is particularly susceptible to strong storm surges
 - Shallow sloping sea floor
 - At the top of a funnel-shaped bay

Galveston, TX: 1900

- Galveston was a booming as a center of trade (“New York of the Gulf”).
- Biggest city in Texas (population 36,000).
- In 1875 nearby Indianola was second to Galveston among Texas port cities, but was destroyed by a hurricane, rebuilt and destroyed again 1886.
- Developers ignored stories that an 1841 storm had submerged the entire island

Texas Coast



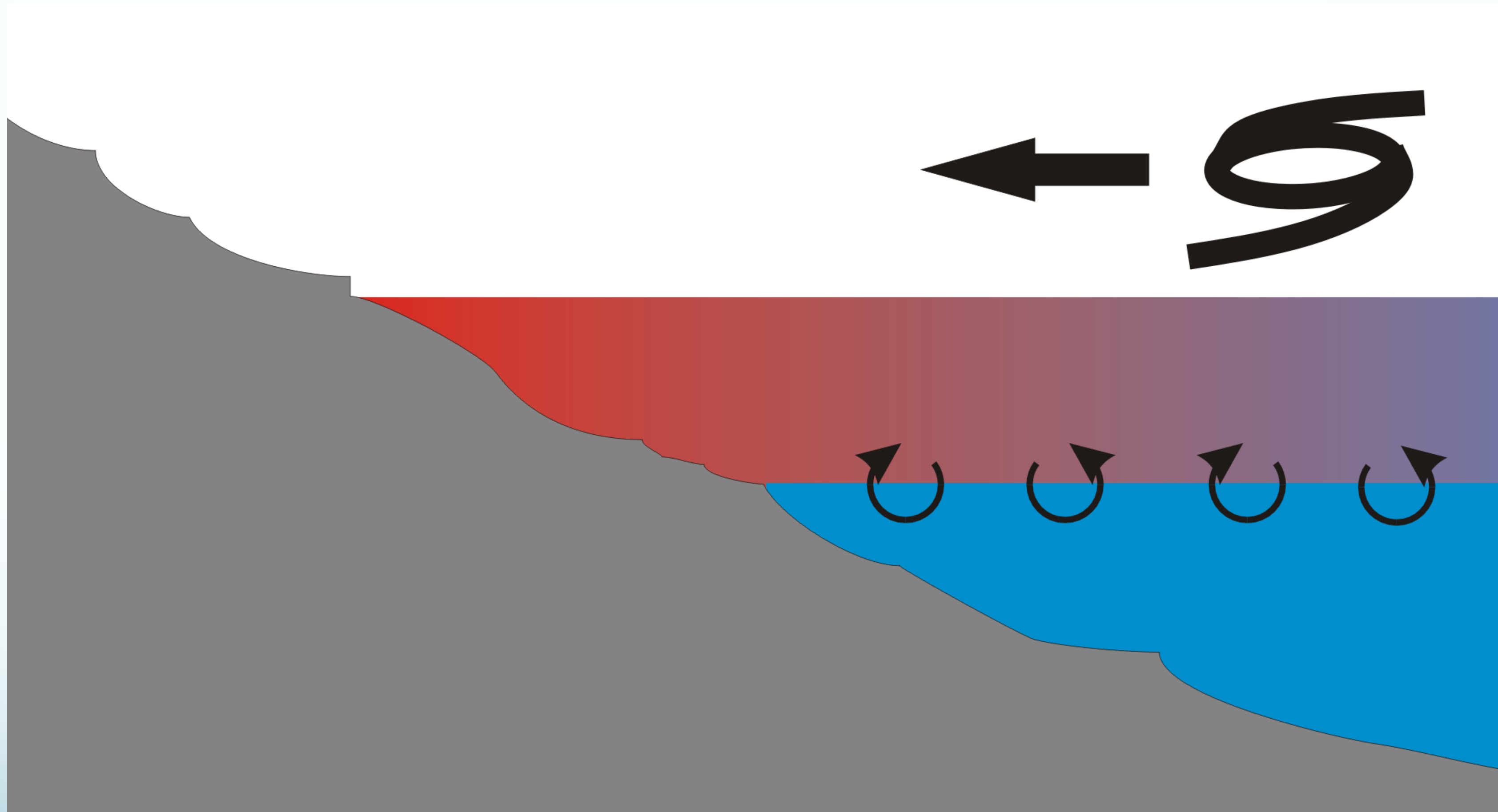
Galveston, TX: 1900

- Sea wall for Galveston was proposed, but there was not sufficient support for construction.
- No serious problems with hurricanes in the previous 50 years.
- Scientists had published papers arguing severe storm surges were impossible in Galveston because of the gently sloping sea bottom.
 - Destruction of Indianola by storm surge in 1875 and 1886 was ignored.

Gentle Bottom Slope Actually Makes Things Worse

- Shallow slope is more favorable for storm surge.
- Shallow slope prevents cold water from mixing upward to the surface while the hurricane is approaching
 - Cold surface waters weakens the storm

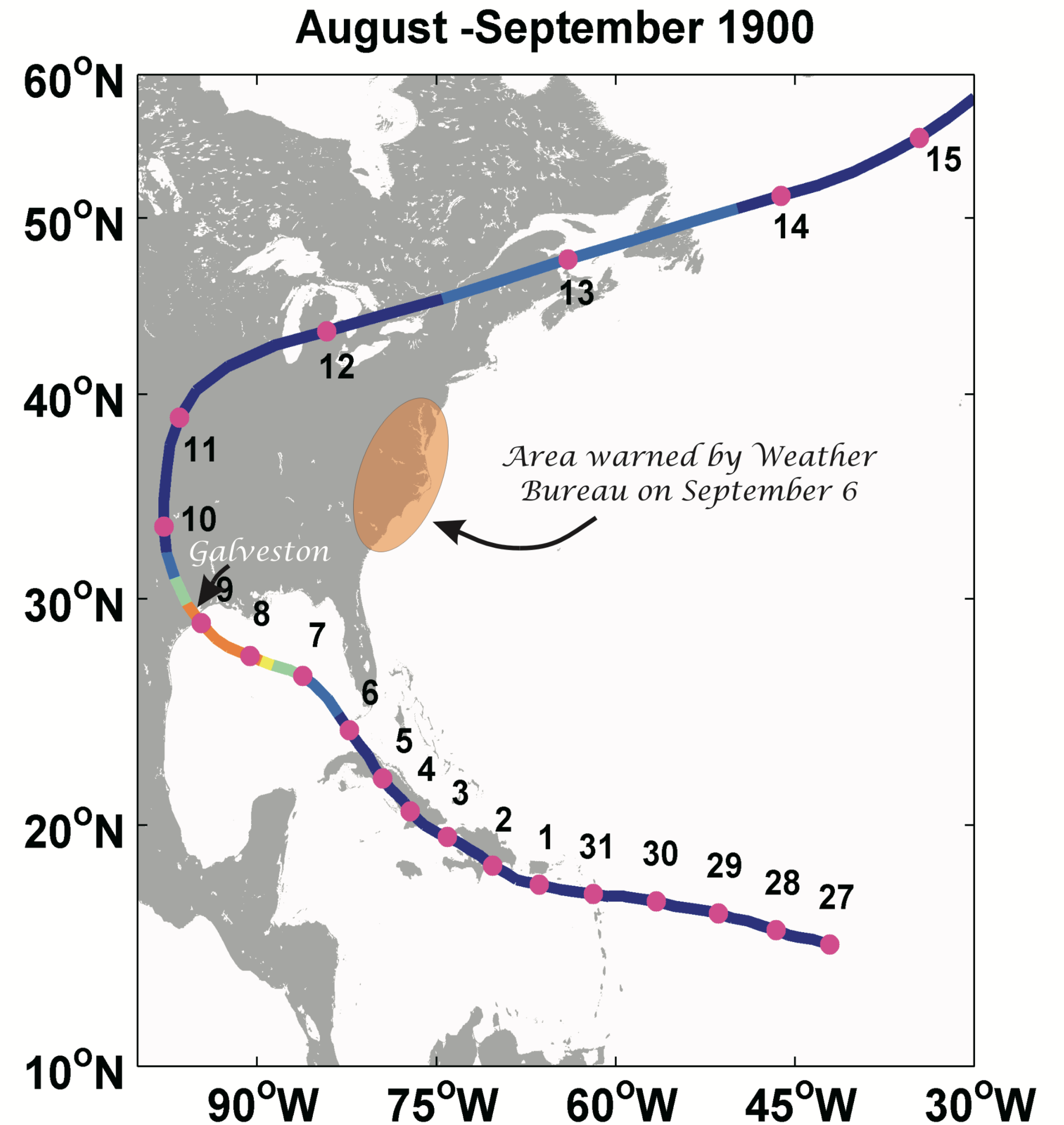
Shallow Bottom Prevents Cold Water from Reaching Surface



Taken by surprise

September 8, 1900

- Warnings from Cuban forecasters ignored
- 15' storm surge
- Galveston Island was only 8' above sea level



Galveston: 1900



Galveston Damage: 1900

