Spiderwebs and Ice

THE STORM ENTERED the Caribbean Sea early on Friday morning, August 31, in a confetti of sparks and thunder, with increased winds that raised from the sea patches of dense foam and streaks of spindrift. In the cloudlight of morning the sea was a dead gray scabbed with green. Rain began falling on St. Kitts, an island west by northwest of Antigua. What made this rain unusual was the fact it did not deplete the clouds overhead. The storm only got bigger.

As vapor rose through the clouds and began to condense, it deposited its moisture on tiny bits of airborne debris, ranging from submicroscopic "Aitken" nuclei to pollen, spiderwebs, volcanic ash, steamship exhaust, Saharan dust, even the pulverized ferrous salts of meteors disintegrated in the atmosphere. Somewhere over St. Kitts, a giant plume of water, ice, and aerosol debris rocketed through the troposphere getting colder and colder until it penetrated the stratosphere, where it entered a realm of new warmth caused by direct radiation from the sun. Suddenly the plume was colder than the air around it. It lost buoyancy. It arced against the hard blue of the stratosphere and fell back toward the earth.

This descending air met air still rising from below. Falling droplets met ascending droplets. The collisions formed bigger drops and the bigger they grew, the faster they fell. Now they overtook other falling droplets and grew bigger still. A raindrop four-hundredths of an inch in diameter falls at nine miles an hour; a droplet six times as large falls at twenty. Billions of droplets now got bigger and bigger until they achieved terminal velocities capable of propelling them all the way to the ground.

Under ordinary circumstances, the process of rain production depletes clouds. The "sink rate," or the rate at which water leaves a cloud, exceeds the supply of moisture arriving from the air and sea below, causing clouds to dissipate like ghosts returning to the afterworld. But hurricanes defeat this cycle. They use wind to harvest moisture and deliver it to their centers. As the wind races along the surface of the sea, it increases the rate of evaporation and captures spindrift and foam. The faster the wind blows, the more vapor it picks up and the more energy it transfers to the storm. The resulting surge of condensation and heat in the storm's core causes even greater volumes of air to rush into the sky. Pressure falls again. Wind velocities increase. The cycle repeats itself.

The result can be rainfall more akin to the flow from a faucet than from a cloud.

In 1979 a tropical storm named Claudette blew off the Gulf of Mexico near Galveston and deluged the town of Alvin, Texas, with forty-two inches of rain in twenty-four hours, still the U.S. record for sheer intensity. A Philippine typhoon holds the world's record, dropping 73.62 inches in twenty-four hours. Total accumulations have been higher, however. Ninety-six and a half inches of rain once fell on Silver Hill, Jamaica, over four days. That's eight feet. In 1899 a hurricane dropped an estimated 2.6 billion tons of water on Puerto Rico. Hurricane Camille, which came ashore on the Gulf

Coast in August 1969, was still flush with water two days later when it reached Virginia. With no advance warning from the Weather Bureau, it jettisoned thirty inches of rain in six hours. Hillsides turned to mud, then to an earthen slurry that flowed at highway speeds. In Virginia alone, 109 people lost their lives.

Camille's rain fell with such ferocity it was said to have filled the overhead nostrils of birds and drowned them from the trees.

heard over the wind, rain, and barrage of debris, they start shouting. "Are you deaf, Isaac?" Joseph perhaps cries. "What do you think that is, for God's sake? An evening breeze? This house will not stand. Out there at least we have a chance."

Isaac prevailed. Joseph, frustrated, began offering advice for how best to survive the coming collapse. "I urged them, if possible, to get on top of the drift and float upon it when the dangerous moment came. As the peril became greater, so did the crowd's excitement. Most of them began to sing; some of them were weeping, even wailing; while, again, others knelt in panic-stricken prayer. Many of them were scrambling aimlessly about, seeking what, in their fright, appeared to be vantage points."

The battering continued. By now all four galleries had been torn from Isaac's house, all slate stripped from its roof.

The trestle was a yard away.

IN DALLAS, THREE hundred miles north, the telegraph operator at the Dallas *News*, sister to the Galveston *News*, realized the steady flow of cables from the Galveston paper had ceased. The two newspapers maintained a leased telegraph line that ran directly between their editorial offices. The telegrapher at the Dallas paper keyed off an inquiry, but got no response. He tried again. Again nothing. He then tried raising Galveston over public lines by relay through Beaumont, and next by sending a message to Vera Cruz, Mexico, for relay to Galveston via the Mexican Cable Company (whose Galveston agent had only a few hours to live).

Again he failed.

At that moment, City Editor William O'Leary was in the office of the Dallas paper's manager, G. B. Dealey, showing Dealey a passage in Matthew Fontaine Maury's best-selling *Physical Geography of the Sea* that seemed to show "that destruction of Galveston by tropical storm could not happen."

The wires remained dead.

THE LEVY BUILDING

Vital Signs

SATURDAY EVENING, JOHN Blagden, the new man temporarily assigned to Galveston, found himself alone in the office. He had been in the city all of two weeks and here he was alone in the dark, facing a storm whose intensity seemed to place it in the realm of the supernatural.

The Levy Building was four stories tall and made of brick but in some gusts, Blagden said, it "rocked frightfully." Bornkessell, the station's printer, had left for home first thing in the morning. Isaac had gone home next, followed by Joseph. Ernest Kuhnel, a clerk, was supposed to be in the office but had fled the building in terror.

The storm flag was gone, as were the anemometer, rain gauge, and sunshine recorder. The telephone had stopped ringing. There was nothing for Blagden to do but watch the barometer and try to keep himself sane. He estimated the wind at 110 miles an hour.

The hurricane had set a course toward Galveston soon after leaving Cuba, and had stayed on that course ever since, as if it had chosen Galveston as its target. It had a different target, however. The great low-pressure zone that had formed over the Pacific Coast earlier in the week had progressed to where it now covered a broad slice of the nation from Texas to Canada. The hurricane saw this low-pressure zone as a giant open door through which it could at last begin its northward journey.

The storm's track intersected Galveston's coastline at a ninety-degree angle, with the eye passing about forty miles west of the city somewhere between Galveston and the Brazos River. Meteorologists discovered this later when officers aboard an Army tug stationed at the mouth of the Brazos reported a pattern of winds that showed the eye had passed somewhere east of their position. The pattern in Galveston indicated the eye had passed to the west of the city. This was the worst-possible angle of approach, for it brought the hurricane's most-powerful right flank directly into the city.

Blagden knew nothing of the storm's track. What he did know was that the first shift in wind direction, from north to northeast, had brought a sudden acceleration in wind speed. And now he sensed the wind beginning to shift again, toward the east. Impossibly, the change seemed to bring another increase in velocity. Gusts struck the building like cannonballs.

Barometric pressure had fallen all day, but at five o'clock Galveston time it began to fall as if someone had punched a leak into the instrument's mercury basin. At five, the barometer read 29.05 inches.

Nineteen minutes later, 28.95.

At 6:40 P.M., 28.73 inches.

Eight minutes later, 28.70.

An hour later, the barometer read 28.53 inches, and continued falling. It bottomed at 28.48.

Blagden had never seen it that low. Few people had. At the time, it was the lowest reading ever recorded by a station of the U.S. Weather Bureau.

In fact, the storm drove the pressure even lower, although just how far will always be a mystery. The bureau's instruments in the Levy Building captured pressures well away from the center of the eye, where the pressure would have been lowest.

Barometers elsewhere in the city got widely varied readings. In Galveston harbor, the first mate of the English steamer *Comino,* moored at Pier 14, recorded in the ship's log a pressure of 28.30 inches, and noted: "Wind blowing terrific, and steamer bombarded with large pieces of timber, shells, and all manner of flying debris from the surrounding buildings." At one point the wind picked up a board measuring four feet by six inches and hurled it with such velocity it pierced the *Comino*'s hull. The hull was built of iron plates one inch thick. In the train station, the scientist with the barometer—apparently unaware of his fast-eroding popularity—called out a pressure of 27.50 inches, and announced that against such impossibly low pressures "nothing could endure."

Years later, scientists with NOAA put the lowest pressure of the storm a notch lower, at 27.49.

In 1900, however, even Blagden's reading of 28.48 stretched credibility. "Assuming that the reading of the barometer reported at Galveston the evening of the 8th was approximately correct," wrote one of Moore's professors, carefully hedging for error, "the hurricane at that point was of almost unparalleled severity."

The highest speed recorded by the Galveston station's anemometer before it blew away was 100 miles per hour. The bureau later estimated that between 5:15 P.M. and 7 P.M. Galveston time, the wind reached a sustained velocity of "at least" 120 miles per hour.

Most likely the true velocity was far greater, especially within the eyewall itself. Gusts of two hundred miles an hour may have raked Galveston. Each would generate pressure of 152 pounds per square foot, or more than sixty thousand pounds against a house wall. Thirty tons.

As John Blagden sat in his office, powerful bursts of wind tore off the fourth floor of a nearby building, the Moody Bank at the Strand and 22nd, as neatly as if it had been sliced off with a delicatessen meat shaver. Captain Storms of the *Roma* had practically bolted his ship to its pier, but the wind tore the ship loose and sent it on a wild journey through Galveston's harbor, during which it destroyed all three railroad causeways over the bay. The wind hurtled grown men across streets and knocked horses onto their sides as if they were targets in a shooting gallery. Slate shingles became whirling scimitars that eviscerated men and horses. Decapitations occurred. Long splinters of wood pierced limbs and eyes. One man tied his shoes to his head as a kind of helmet, then struggled home. The wind threw bricks with such force they traveled parallel to the ground. A survivor identified only as Charlie saw bricks blown from the Tremont Hotel "like they were little feathers."

All this was nothing, however, compared to what the wind had been doing in the Gulf of Mexico. Ever since leaving Cuba, the storm had piled water along its leading edge, producing a dome of water that twentieth-century meteorologists would call a storm surge.

Early scientists believed that reduced pressure alone accounted for storm tides. By the mid-nineteenth century, however, they came to understand that a one-inch decline in pressure raised the sea only a foot. Thus even a pressure as low as 27.49 inches would cause the sea to rise only two and a half feet. Yet the Galveston storm shoved before it a surge that was over fifteen feet deep.

The single most important force needed to build a storm surge is wind. A strong wind will develop a surge in any body of water. A fan blowing across a water-filled container will cause the water to swell at the downwind side. Strong winds blowing over some of Minnesota's biggest northern lakes will pile ice to the height of a McDonald's sign. One of the deadliest storm surges in American history occurred on Lake Okeechobee in Florida, in 1928, when hurricane winds blowing across the long fetch of the lake raised a storm surge that killed 1,835 people.

Another ingredient is geography. In 1876 Henry Blanford, a meteorologist in India, proposed that the configuration of the Bay of Bengal contributed greatly to the immense storm tides that came ashore during typhoons. Blanford thought of these tides as great waves. Every cyclone raised them, "but it is only when the wave thus formed reaches a low coast, with a shallow shelving foreshore, such as are the coasts of Bengal

and Orissa, that, like the tidal wave, it is retarded and piled up to a height which enables it to inundate the flats of the maritime belt, over which it sweeps with an irresistible onset."

Despite such reports, Isaac and his colleagues in the bureau believed that a hurricane's most lethal weapon was the wind. They did not see the parallels. Isaac, like the famous Commodore Maury, believed the shallow slope of the seabed off Galveston would wear down incoming seas before they struck the city, and had argued in his 1891 *News* article that mainland areas north of Galveston Bay would serve as basins to capture whatever floodwaters a storm did manage to drive ashore.

The hurricane of 1900 would cause a hasty reevaluation. In October, in the Weather Bureau's *Monthly Weather Review,* one of the bureau's leading lights, Prof. E. B. Garriott, belatedly observed that Galveston's geography and topography in fact "render it, in the presence of severe storms, peculiarly subject to inundation."

A storm's trajectory can also increase the destructive power of a surge. If a hurricane strikes at an oblique angle, it spreads its storm surge over a broader swath of coast, thereby dissipating the surge's depth and energy. The Galveston hurricane struck the Texas coast head-on, at a nearly perfect ninety-degree angle, after traveling a long, unobstructed fetch of some eight hundred miles. The track focused the onshore flow directly into the city.

The track produced another lethal effect, however. It brought north winds to Galveston Bay twenty-four hours before landfall. Throughout most of Saturday, these intensified to gale force and finally to hurricane force. Due north of Galveston Island, the bay offers an unobstructed fetch of about thirty-five miles (about the same fetch as presented by Lake Okeechobee). And just as in the freak Galveston blizzard of February 1899, the wind blew the water out of Galveston Bay—this time into the city itself.

In effect, the storm's trajectory made Galveston the victim of two storm surges, the first from the bay, the second from the Gulf, and ensured moreover that the Gulf portion would be exceptionally severe. Throughout the morning, the north winds kept the leading edge of the Gulf surge out at sea, banking the water and transforming the Gulf into a compressed spring, ready to leap forward the moment the winds shifted.

The first shift, from north to east, began at about two o'clock Saturday afternoon, Galveston time. This allowed some of the Gulf surge to come ashore. Water flowed over the Bolivar Peninsula and began rising within the shaft of the Bolivar Light. It flowed too over Fort San Jacinto and Galveston's East Side, where it met the floodwater already driven into the city from the bay. The reason so many men and women in Galveston began furiously chopping holes in their beloved parlor floors was to admit the water and, they hoped, anchor their homes in place.

At 7:30 P.M., the wind shifted again, this time from east to south. And again it accelerated. It moved through the city like a mailman delivering dynamite. Sustained winds must have reached 150 miles an hour, gusts perhaps 200 or more.

The sea followed.

Galveston became Atlantis.

AVENUE P ½

The Wind and Dr. Young

ABOUT SEVEN O'CLOCK, Dr. Young heard a heavy thumping that seemed to come from a downstairs bedroom on the east side of his house. He lit the candle that he had held in reserve and walked toward the hall stairwell, the candle throwing only a shallow arc of light on the floor around him. Pistol-shot drafts penetrated deep within the house and caused the candle's flame to twist, but did nothing to cool the rooms. At the Levy Building about then John Blagden was recording a temperature of 84.2 degrees. The shock of each thump vibrated through the floor of Young's house. It was as if someone were standing in the downstairs bedroom striking the ceiling with a railroad mallet.

The stairwell appeared ahead as a large black rectangle stamped from the floor, and the closer Young got, the deeper the candlelight traveled. It should have shown him stairs and the wood slats of the banister, but he saw neither, only an orange glow undulating on the opposite wall like sunlight off a floating mirror.

Water, he realized. The sea had risen within his house nearly to the top step. The heavy thudding from the bedroom had to be furniture. A bureau, perhaps, bumping against the ceiling as the water rose and fell.

Young set the candle on the floor and walked to the door that led to his second-floor gallery. He opened it. "In a second I was blown back into the hall."

The wind snuffed the flame, then blew the candle and its holder to the far reaches of the house. From within the darkness of the hall, the