We have a few items noting the tenth anniversary of Katrina's visit to New Orleans. First from **Wired Magazine** a series of graphics that show the paths of the last 160 years of hurricanes in North America. The first is for category one and so on. The last shows all storms. There are no dates or names, but the swarm informs. These are large files so we have to pass on any cartoons today.

The **Wall Street Journal** reports on the Katrina diaspora in Houston, TX.
HOUSTON—Before Hurricane Katrina, Danny Cook was working three low-paying jobs in New Orleans and struggling to pay rent and tuition for a master's program in computer science.

Now, 10 years after he was rescued by a helicopter in the wake of the storm and boarded a bus headed to Houston, he has built a life here that he said would have been impossible in his former city. He bought a home, started a business and continued his studies.

"It has been a miracle," said Mr. Cook, 39 years old, sitting in his living room, beside a set of shelves bearing his diplomas.

He is one of tens of thousands of people uprooted by Katrina who ended up settling permanently in new cities such as Atlanta and San Antonio. The storm scattered evacuees across 45 states and the District of Columbia, though most landed in the South, according to U.S. Census data.

A 2008 Bureau of Labor Statistics study found that about 410,000 of the roughly 1.5 million people from Louisiana, Mississippi and Alabama who were displaced hadn't returned to their homes more than a year after the storm. How many still haven't gone back is uncertain, because tracking their whereabouts became increasingly difficult with time, researchers say. ...

From **Five Thirty Eight** we learn about the results of school reforms in post Katrina New Orleans.
Ten years after Hurricane Katrina, the city of New Orleans is still debating the merits of Louisiana's experimental overhaul of its flooded schools. But research released this month signals that student outcomes in the city have improved and that the reforms are responsible.

Before Katrina, New Orleans had a traditional public school system. At the time of the August 2005 flood, that district was the second-worst-performing district in the second-worst-performing state. Now, it's the country's first free-market education system. Whether New Orleans's radical reforms have worked matters not only for students there, but also for kids in classrooms around the country where similar models are being applied.

In November 2005, the Louisiana State Legislature voted to allow the state-run Recovery School District, which had been created to take over failing schools across Louisiana, to take control of 102 of 117 schools in the city (on top of the five it already controlled). Under pressure to reopen schools as quickly as possible, the Orleans Parish School Board fired all the public school employees, and the board and the Recovery School District turned the schools over to organizations to run as charters. According to the Cowen Institute at Tulane University, 93 percent of New Orleans public school students attended charter schools in the 2014-15 school year — the highest proportion in the country.

With the influx of charter schools came a suite of other reforms, including greater school autonomy, open enrollment, reliance on nonprofits such as Teach for America to provide

training and staff, and accountability measures that allowed the state to close underperforming schools. By the available metrics, these reforms have been a success. But it's difficult to assess other consequences — like community engagement and trust in the process — that are less quantifiable. ...

From hurricanes to earthquakes (Segues are Us!) we learn from **Physics World** that radon emissions might predict earthquakes. Apparently we can get a warning when the earth breaks wind.

A combined analysis of the concentrations of radon and one of its radioactive isotopes called "thoron" may potentially allow for the prediction of impending earthquakes, without interference from other environmental processes, according to new work done by researchers from Korea. The team monitored the concentrations of both isotopes for about a year and observed unusually large peaks in the thoron concentration only in February 2011, preceding the Tohoku earthquake in Japan, while large radon peaks were observed in both February and the summer. Based on their analyses, the researchers suggest that the anomalous peaks observed in that month were precursory signals related to that earthquake that followed the following month.

Earthquake prediction remains the holy grail of geophysics, and an oft-proposed but highly contested method for quake forecasting revolves around the detection of abnormal quantities of certain gaseous tracers in soil and groundwater. These are believed to be released through pre-seismic stress and the micro-fracturing of rock in the period immediately before an earthquake. ...

Live Science has 20 startling facts about insects. (The real insects, not the ones in Washington. We'll get to them tomorrow.)

Almost everywhere you look, you'll find one — or dozens — of the six-legged critters called insects. A wildly diverse bunch, the class Insecta includes ants, bees, flies, beetles and much more. These creatures all possess a body composed of three segments — head, thorax and abdomen — encased in a hard exoskeleton. All insects also sport a pair of antenna, compound eyes and three pairs of jointed legs. From that basic body plan, emerge all sorts of amazing behaviors and abilities, as Live Science reveals here in 20 startling facts about insects.

1. The most successful creatures. *To date, scientists have catalogued about 1.5 million species of organisms on the planet, with insects making up about two-thirds of this bounty, researchers report in the journal Proceedings of the National Academy of Sciences. But scientists have only begun to scratch the surface: Studies estimate the total number of species on Earth is probably closer to 9 million. Of the planet's wildly diverse collection of creatures, some 90 percent of species are reckoned to belong to the class Insecta. Reasons for insects' success include their tiny size, which both makes hiding easier and reduces overall energy requirements; wide diet of both natural and artificial foods; tough, protective exoskeletons; frequent possession of wings, which help them reach safety, grub and mates; and prodigious ability to reproduce. ...*

WIRED

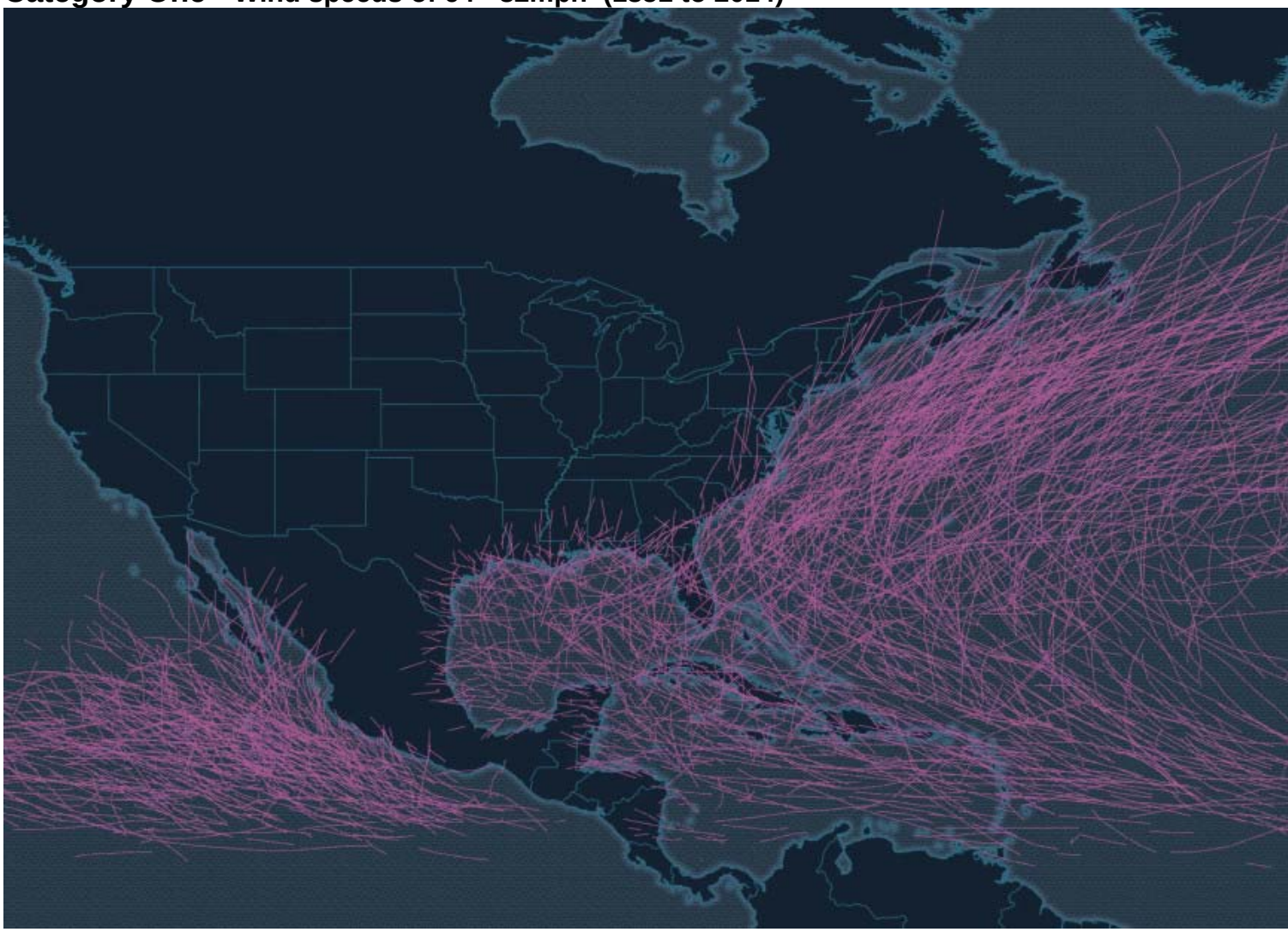
160 years of hurricanes in North America

Tracks by category 1 - 5

Ten years ago this month, Hurricane Katrina hit the Gulf Coast. It was one of four major storms to make landfall in the US that year, and 2005 remains among the worst Atlantic hurricane seasons on record, causing as many as 4,000 deaths across the Atlantic Basin and more than $100 billion in damages. Since then it's been relatively quiet on the eastern front—the longest US hurricane drought on record, according to climate scientists.

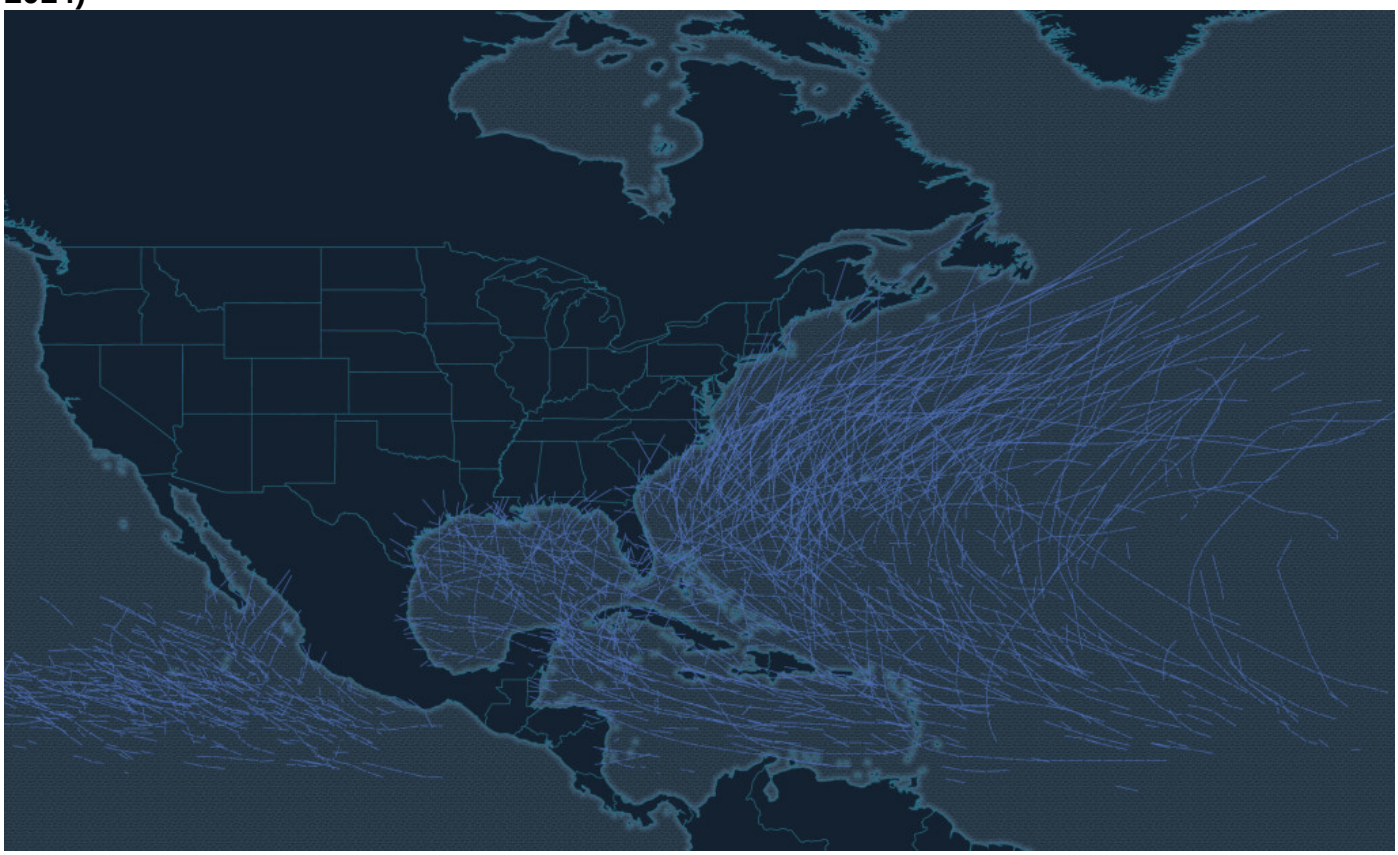
Americans haven't been smacked with anything worse than a Category 2 since October 2005. The lack of megastorms in the past decade is just luck, researchers say, and this season is expected to be calmer than average too. At least on that side of the world. Experts from University College London predict that the Northwest Pacific typhoon season will be the most active since 2004. While there's no sure way to foresee where hurricanes will pop up, we do know where they've been.

Category One - Wind speeds of 64 - 82mph (1851 to 2014)



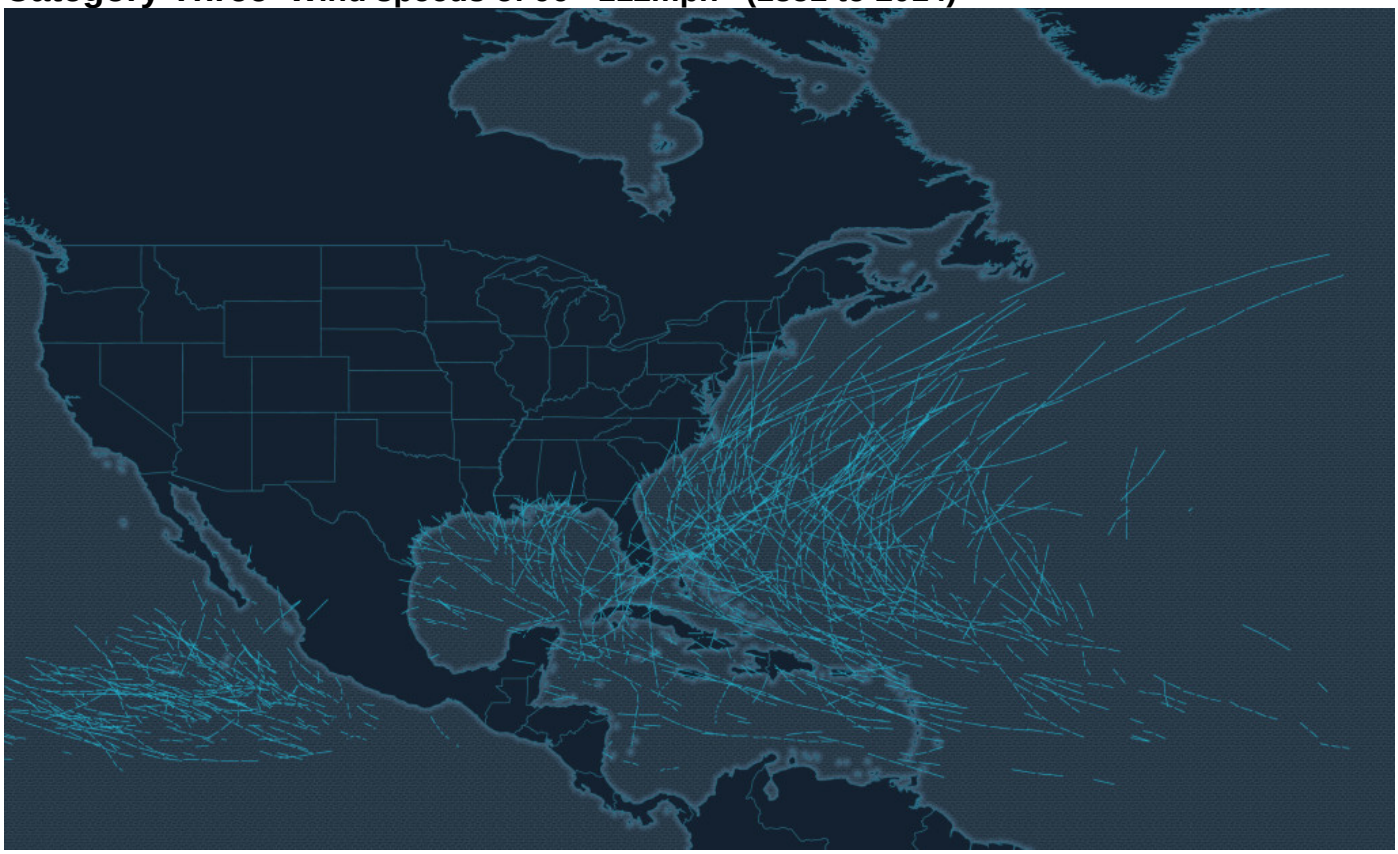
Cat. one

Category Two - Wind speeds of 83 - 95mph (1851 to 2014)



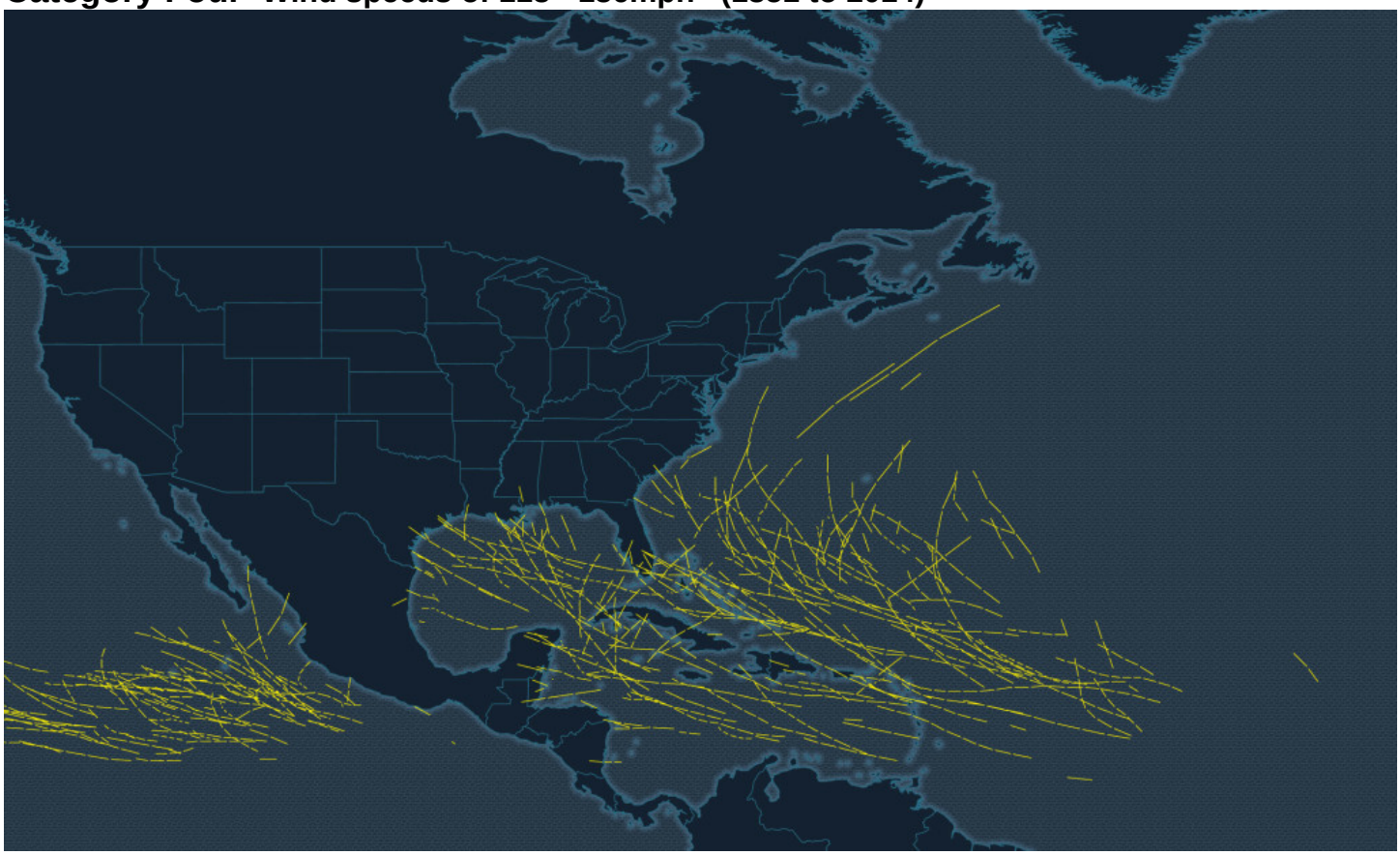
Cat. two

Category Three Wind speeds of 96 - 112mph (1851 to 2014)



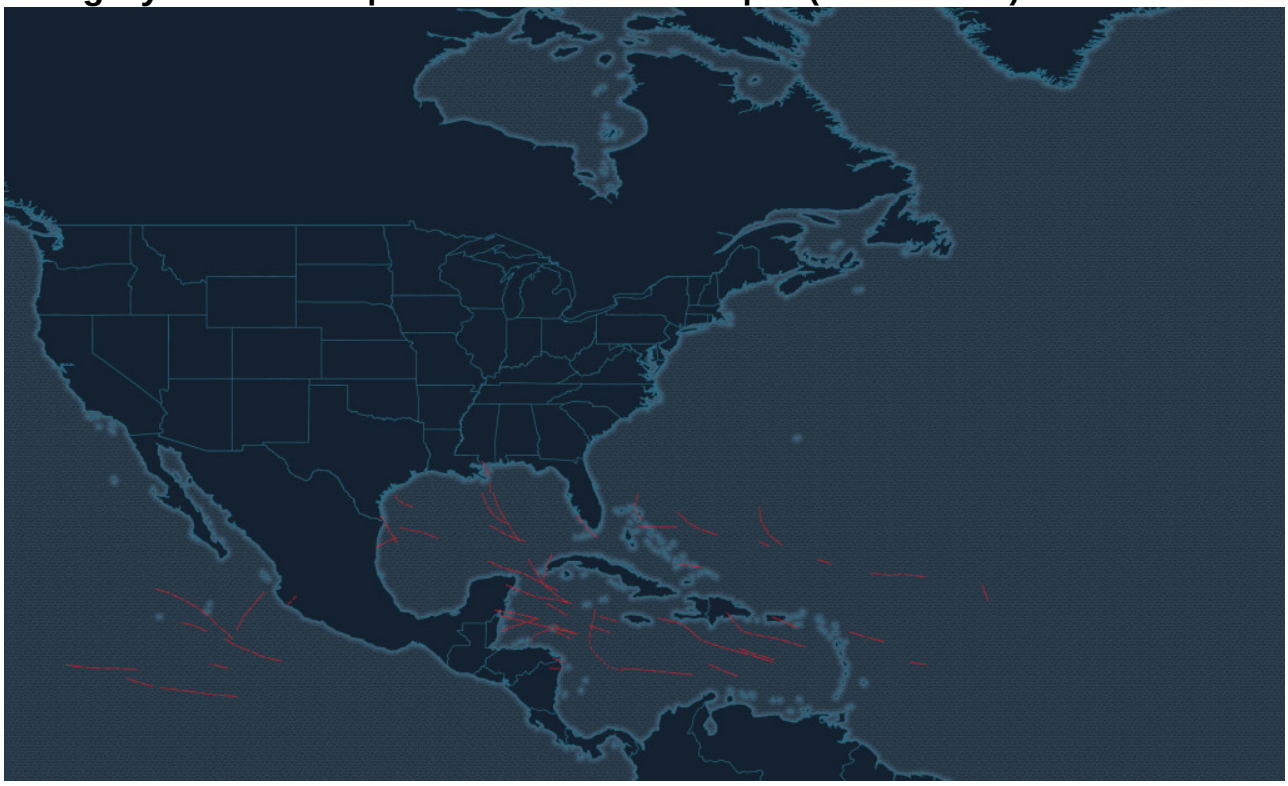
Cat. three

Category Four **Wind speeds of 113 - 136mph (1851 to 2014)**



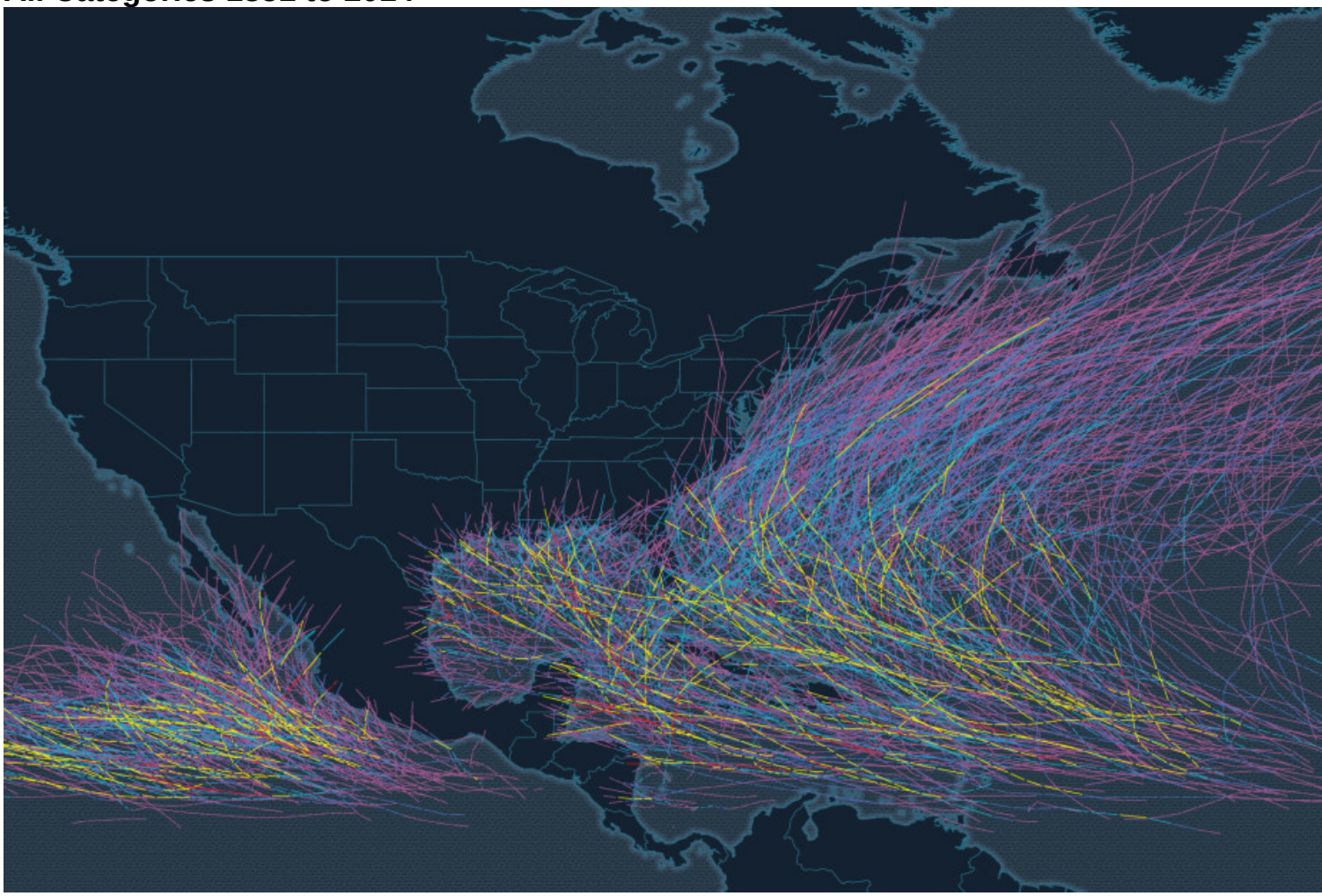
Cat. four

Category Five **Wind speeds in excess of 137mph (1851 to 2014)**



Cat. five

All Categories 1851 to 2014



All categories

WSJ

Members of Hurricane Katrina Diaspora in Houston Look Back at the Past 10 Years

Some New Orleans evacuees have thrived in Houston, but one complains 'there's no real culture here'

by Arian Campo-Flores

HOUSTON—Before Hurricane Katrina, Danny Cook was working three low-paying jobs in New Orleans and struggling to pay rent and tuition for a master's program in computer science.

Now, 10 years after he was rescued by a helicopter in the wake of the storm and boarded a bus headed to Houston, he has built a life here that he said would have been impossible in his former city. He bought a home, started a business and continued his studies.

"It has been a miracle," said Mr. Cook, 39 years old, sitting in his living room, beside a set of shelves bearing his diplomas.

Danny Cook, 39, moved to Houston after being rescued from flood waters in the aftermath of Hurricane Katrina. Despite the challenges of relocating and struggling to start businesses, Mr. Cook believes he found opportunities in Houston that he would have never had in New Orleans.

He is one of tens of thousands of people uprooted by Katrina who ended up settling permanently in new cities such as Atlanta and San Antonio. The storm scattered evacuees across 45 states and the District of Columbia, though most landed in the South, according to U.S. Census data.

A 2008 Bureau of Labor Statistics study found that about 410,000 of the roughly 1.5 million people from Louisiana, Mississippi and Alabama who were displaced hadn't returned to their homes more than a year after the storm. How many still haven't gone back is uncertain, because tracking their whereabouts became increasingly difficult with time, researchers say.

Many evacuees had trouble establishing themselves. The BLS study showed that more than a year after Katrina, the unemployment rate among evacuees who didn't return to their home counties was about 19%, more than double the rate among those who did.

For cities on the receiving end, the effects have been mixed. In Baton Rouge, La., where the metropolitan region's population jumped by nearly 60,000 residents the year after Katrina, the influx initially created traffic congestion and strained schools. But it also has contributed to Baton Rouge's economic expansion, as a variety of New Orleans companies, from manufacturers to law firms, opened new offices or expanded existing ones in the city, said Adam Knapp, chief executive of the Baton Rouge Area Chamber.

Outside Louisiana, the largest group of evacuees settled in Houston. Of the 150,000 to 200,000 people who initially arrived in the city, an estimated 20,000 to 40,000 remain, said Mtangulizi Sanyika, chairman of the New Orleans Association of Houston, an advocacy group.

At first, many of the arrivals struggled, said Ann Hilbig, a vice president at Neighborhood Centers Inc., a not-for-profit organization that provided services for evacuees. They had to navigate a big, sprawling city without the support of family and social networks, she said. Those who managed to get a foothold often had skills or degrees in key industries such as construction, health care and oil and gas.

Katrina evacuees have made their mark on the city. They include barbers, brass-band players and bankers. They have opened eateries with names like Big Easy Express and established congregations including the local branch of New Orleans's Franklin Avenue Baptist Church.

Some stayed because they had little to return to. "I had to start all over again," said Ebony Handy, 41, whose home in New Orleans's Lower Ninth Ward had to be demolished. She now works as a medical lab technician and lives with her mother, sister and aunt in a house they bought a year after arriving.

Ebony Handy, 41, center, is one of an estimated 20,000 to 40,000 Katrina evacuees who remain in Houston. Her New Orleans home was destroyed by the storm, and she was forced to start a new life, which includes being a part of the local branch of New Orleans's Franklin Avenue Baptist Church, established by other Katrina evacuees.

For Terrence and Zeeda Veal, Houston offered better schools for their six children and more job opportunities. Mr. Veal, 33, drives a truck for FedEx Corp., records hip-hop music and plans to become a school teacher. Mrs. Veal, 43, works as a fitness instructor and recently completed an autobiography that she self-published. "Houston was an awakening," she said.

Zeeda Veal, second from left, and Terrance Veal, second from right, chat with family members after dinner at their home in Houston on Aug. 23. The Veal family and many of their relatives were displaced by Hurricane Katrina. Upon arrival in Houston, they crammed 22 people into an apartment as they adjusted to life in their new city.

Not everyone is as enthused about the city. “I don’t feel at home,” said Lakesha Reed, 38, who opened two locations of the Beaucoup Bar & Grill. “There’s no real culture here.” Although it has been rewarding to start her own business, she said, “I definitely will move back to New Orleans” one day.

Mr. Cook’s experience in Houston began when he got off the bus at the Astrodome, alone and bearing just two bags of belongings. He had been rescued from floodwaters in New Orleans East, where he had abandoned his apartment, cars and other belongings. He reached out to the only people he could think of: leaders of a Christian drill team he had met through his church. They took him in and helped him find a job as a collection agent.

Soon after, Mr. Cook received a letter inviting him to apply for a subsidized house that was part of a community being built for Katrina evacuees through a collaboration between Oprah Winfrey and Habitat for Humanity. He ended up qualifying and in 2007 moved into a three-bedroom home that required only a $500 down payment. “It was almost like dying and going to heaven,” he said.

Katrina dispersed other members of Mr. Cook’s family as well. His mother and one of his brothers settled in Des Moines, Iowa, while another brother put down roots in Tulsa, Okla.

Mr. Cook eventually landed a job in his preferred field, information technology, at the University of Houston-Downtown. Later, he struck out on his own, founding a computer repair and sales business he named G.S. Technology Solutions, for “God Sent.” He went back to school to complete a master’s in computer science at Texas Southern University, where he is scheduled to graduate in December.

Things haven't always gone smoothly. Business has been erratic, and Mr. Cook has gone through two bankruptcy proceedings. Still, he said, he has achieved far more than he would have in New Orleans. "This was my blessed place," he said. "I've come a long way since Katrina."

Five Thirty Eight

Test Scores Don't Tell Us Everything About New Orleans School Reform

by Hayley Munguia

Ten years after Hurricane Katrina, the city of New Orleans is still debating the merits of Louisiana's experimental overhaul of its flooded schools. But research released this month signals that student outcomes in the city have improved and that the reforms are responsible.

Before Katrina, New Orleans had a traditional public school system. At the time of the August 2005 flood, that district was the second-worst-performing district in the second-worst-performing state. Now, it's the country's first free-market education system. Whether New Orleans's radical reforms have worked matters not only for students there, but also for kids in classrooms around the country where similar models are being applied.

In November 2005, the Louisiana State Legislature voted to allow the state-run Recovery School District, which had been created to take over failing schools across Louisiana, to take control of 102 of 117 schools in the city (on top of the five it already controlled). Under pressure to reopen schools as quickly as possible, the Orleans Parish School Board fired all the public school employees, and the board and the Recovery School District turned the schools over to organizations to run as charters. According to the Cowen Institute at Tulane University, 93 percent of New Orleans public school students attended charter schools in the 2014-15 school year — the highest proportion in the country.

With the influx of charter schools came a suite of other reforms, including greater school autonomy, open enrollment, reliance on nonprofits such as Teach for America to provide training and staff, and accountability measures that allowed the state to close underperforming schools. By the available metrics, these reforms have been a success. But it's difficult to assess other consequences — like community engagement and trust in the process — that are less quantifiable.

Supporters of the reforms have pointed to improved student test scores and graduation rates as an indication that the overhaul was a success. As Jonathan Chait of New York magazine wrote Monday, the reforms "have produced spectacular results." Meanwhile, critics have pointed to the lack of transparency in that data, saying it's unclear whether these measures are accurate, or whether the improvement can be tied wholly to the reforms.

The latest research, conducted by the Education Research Alliance for New Orleans, an organization within Tulane, aimed to find out how significant the improvement in test scores and graduation rates has really been, and to understand what has caused it.

Douglas Harris, the organization's director and the lead author of the report, said any number of factors after the flood could have affected student outcomes.

First, New Orleans shut down the city's largest sources of public housing after Katrina, meaning students from higher-income families returned to the city and to school while others didn't. That change in the makeup of the student population alone would affect scores, but Harris also noted that the schools students attended elsewhere before returning to New Orleans could have had a significant impact on their learning. On the other hand, many of those returning students, Harris said, "came back to a city that was like a third-world country for years afterward," an environment that could have had an adverse effect on student outcomes.

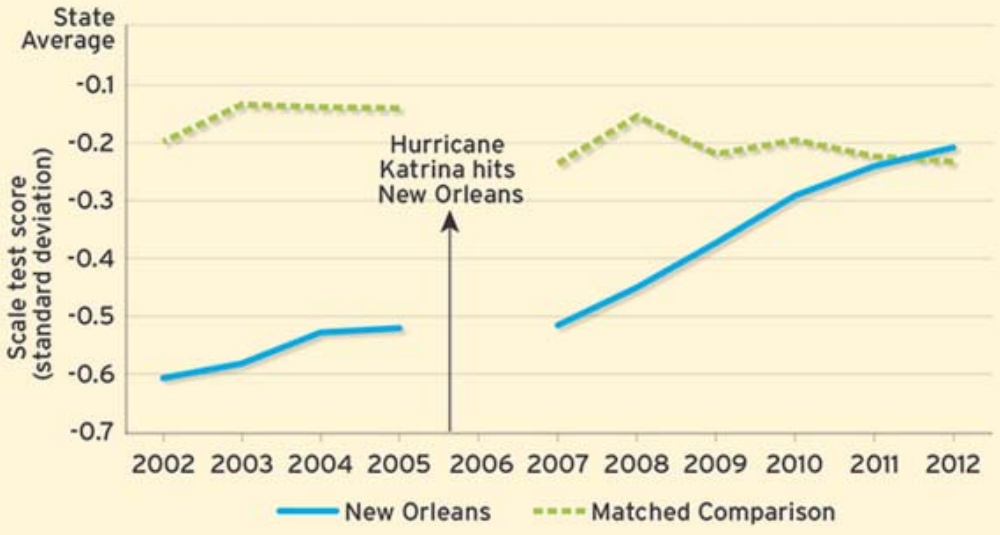
The reforms also allowed the state to close schools that weren't up to par according to Louisiana's School Performance Scores, which are calculated using student test scores, credits and graduation rates. "Whenever you have a system focused on particular measures and the threat of closing down schools, you have to be worried that someone, somewhere, may be affecting the measures in a way that's not reflecting actual improvement," Harris said.

Reform supporters used to point to a general upward trend in student outcomes, but there was no way to show that the reforms specifically were responsible. "Now we've spent the past year, year and a half, really parsing the outcomes, and I think the case is much more convincing," Harris said.

Using other school districts in Louisiana that were affected by Hurricane Katrina as a control group, the report, published in Education Next, found that New Orleans students' performance increased significantly relative to their counterparts.[1]

A New Trajectory (Figure 1)

Following Hurricane Katrina and the reforms enacted in its aftermath, the performance of New Orleans students rose steadily compared to that of students in other Louisiana districts that were affected by the hurricane.



NOTES: Separate analyses show that New Orleans students returning after the storm, who could be studied only through 2009, also made gains relative to their own prior performance, but these differences were often not statistically significant. Scale scores are averaged across grades 3 through 8 and across English Language Arts, math, science, and social studies. Scale scores are standardized so that zero refers to the statewide average.

SOURCE: Author's calculations

None of this is to say that the system is perfect — despite progress, there have been blunders. The district has addressed parents and critics' concerns about a lack of adequate resources for special education, an opaque disciplinary process and no cohesive districtwide application process.

Yet despite the system's failures, its ability to correct itself has been noteworthy. Christine Campbell, senior research analyst and policy director at the University of Washington Bothell's Center on Reinventing Public Education, has studied the New Orleans model and how it's being implemented in other districts around the country. She said this adaptability is important to consider in gauging the system's success.

"They've been really responsive to both positive and negative trends," she said. "They put the power in the hands of educators in such a dramatic way" that it became a lot easier to implement solutions quickly. She gave as an example the district's response to a 2010 lawsuit alleging that it was denying access to students with disabilities. The school system created a fund for special education and worked with nonprofit groups to provide grants to schools that improved their special education graduation rates. "Within a year, not only had they tackled the problem, but they innovated in a way that other places can learn from," Campbell said.

But some problems are more difficult to tackle. The mass firings of teachers that kicked off the reforms didn't sit well with the community, and critics say there wasn't enough input from parents and students in the system overhaul.

One critic is Adrienne Dixson, an associate professor of education at the University of Illinois at Urbana-Champaign who taught in New Orleans in the '90s and whose children went through the school system. She tends to push back against any praise of the changes, citing the lack of community engagement. "How are we counting success? I attend board meetings and community events, and I know that people feel alienated and don't feel a part of the process. I wouldn't count that as success," she said. "I would say that success is an engaged public."

Campbell measures the implementation of districts' reforms across seven variables of school district success. She said her team initially considered only six, but they added a metric for "engagement" after seeing the backlash from the community the reforms in New Orleans caused.

"We realized that when you sit down at a school that's been failing for 20 years, you don't get a lot of kudos for turning it around when you missed educating the community," she said. "What you really need to do is tell them what's going on, give them the options, and let them drive that demand for something better."

While the research from the Education Research Alliance provides some answers, it won't solve the debate over the success of New Orleans school reform. "There was fallout from the reforms in terms of community engagement, but 10 years out and the community still isn't exactly sure what's the right way to go from here," Campbell said. "There's work underway, but there's no easy answer."

Physics World

Could radon and one of its radioactive isotopes reliably predict an earthquake?

A combined analysis of the concentrations of radon and one of its radioactive isotopes called "thoron" may potentially allow for the prediction of impending earthquakes, without interference from other environmental processes, according to new work done by researchers from Korea. The team monitored the concentrations of both isotopes for about a year and observed unusually large peaks in the thoron concentration only in February 2011, preceding the Tohoku earthquake in Japan, while large radon peaks were observed in both February and the summer. Based on their analyses, the researchers suggest that the anomalous peaks observed in that month were precursory signals related to that earthquake that followed the following month.

Earthquake prediction remains the holy grail of geophysics, and an oft-proposed but highly contested method for quake forecasting revolves around the detection of abnormal quantities of certain gaseous tracers in soil and groundwater. These are believed to be released through pre-seismic stress and the micro-fracturing of rock in the period immediately before an earthquake.

Cloudy with a chance of tremors?

While a number of such precursors have been proposed – including radon, chloride and sulphate – their application to earthquake forecasting has not been realized. The problem here lies in how abnormal concentrations of these tracers can also occur through other environmental processes. For example, signals from radon (^{222}Rn) – an easy-to-detect radioactive gas whose short half-life of 3.82 days makes it highly sensitive to short-term fluctuations – can be disrupted by meteorological phenomena and tidal forces. Radon has no stable isotopes, but has a host of radioactive isotopes including a very short-lived isotope called thoron (^{220}Rn, half-life = 55.6 s).

In a new study, Guebuem Kim and Yong Hwa Oh of Seoul National University propose that an underground, dual-tracer analysis – using both radon and thoron – might be able to overcome these limitations. With its half-life of only 56 seconds, measured thoron activity in the stagnant air of a cave should typically be very low if the recording detector is placed sufficiently far (0.2 m) from the cave floor. "Thoron – through diffusive flows – decays away before it reaches the detector," explains Kim. "Thus, at an optimum position, only advective flows of thoron – earthquake precursors – reach the detector."

To test this concept, the researchers took hourly measurements of the radon and thoron concentration in the Seongryu Cave, in eastern Korea's Seonyu Mountain, over a period of

13 months. The cave – which formed around 250 million years ago – is around 330 m long and varies from 1 to 13 metres in height. Recordings were taken in a part of the cave that is isolated from the air flow from the outside, preventing any thoron anomalies that may arise from a wind-induced surface flow along the cave floor.

Unexpected peaks

An unusually large peak in thoron concentration – above those caused by seasonal variations or daily temperature fluctuations, and unexplainable by a precipitation event – was recorded in the February of 2011, preceding the magnitude 9.0 Tohoku earthquake in Japan, 1200 km away, a month later. In contrast, radon peaks were observed not only during February but also in the preceding summer period, when atmospheric stratification is believed to better trap radon within the cave system. While the thoron measurements alone are capable of recording earthquake signals, Kim says, the anomalous peaks detected were clearer when plotted in tandem with radon activity.

The single station used in the study would not be able to localise or assess the magnitude of an impending earthquake, but the team suggest this may be done using a large network of such detectors. Though the researchers undertook their measurements in a natural limestone cave system, the principle could also be applied to man-made caverns, the researchers report, with the method not being dependant on a particular lithology of rock.

Heiko Woith, a hydrogeologist at the Helmholtz-Zentrum Potsdam in Germany who was not involved in the Korean team's work, is sceptical about the new method. "The length of the time series is too short to judge the reliability of a precursor," he says, cautioning that a non-tectonic origin for the thoron anomaly still cannot be ruled out. "Certainly, the radon–thoron approach is interesting to follow in future studies, but it is premature and misleading to call it a new 'reliable earthquake precursor' at this stage," he concludes.

With this initial study complete, the researchers are now looking to further explore the potential of their radon–thoron technique by setting up a remote monitoring system within an artificial cave, powered by a solar panel on the surface. Ultimately, Kim suggests, these system might be deployed on a larger scale.

The research is described in *Scientific Reports*.

Live Science

20 Startling Facts About Insects

by Adam Hadhazy

Almost everywhere you look, you'll find one — or dozens — of the six-legged critters called insects. A wildly diverse bunch, the class Insecta includes ants, bees, flies, beetles and much more. These creatures all possess a body composed of three segments — head, thorax and abdomen — encased in a hard exoskeleton. All insects also sport a pair of antenna, compound eyes and three pairs of jointed legs. From that basic body plan, emerge all sorts of amazing behaviors and abilities, as Live Science reveals here in 20 startling facts about insects.

1. The most successful creatures. To date, scientists have catalogued about 1.5 million species of organisms on the planet, with insects making up about two-thirds of this bounty, researchers report in the journal Proceedings of the National Academy of Sciences. But scientists have only begun to scratch the surface: Studies estimate the total number of species on Earth is probably closer to 9 million. Of the planet's wildly diverse collection of creatures, some 90 percent of species are reckoned to belong to the class Insecta. Reasons for insects' success include their tiny size, which both makes hiding easier and reduces overall energy requirements; wide diet of both natural and artificial foods; tough, protective exoskeletons; frequent possession of wings, which help them reach safety, grub and mates; and prodigious ability to reproduce.

2. Meet the beetles. Beetles, of the insect order Coleoptera, are the most biodiverse group of creatures known, with more than 380,000 species described to date, making up 40 percent of all insect species on the books. When asked what a study of nature tells you about a creator, the British scientist J.B.S. Haldane once reportedly quipped that you can assume such a creator has "an inordinate fondness for beetles." A recent Proceedings of the Royal Society B study suggests the secret to beetle diversity, and likely to that of other insects groups, is their lifestyle versatility. This ensures that their species do not go extinct as readily as, say, mammal or amphibian species.

3. Planet of the ants. Outside in warm temperatures? If so, when you look down you'll probably spy an ant or two or 10 scurrying along. (It's not uncommon to see ants when indoors, either.) The renowned biologists Bert Hölldobler and E. O. Wilson estimated in their Pulitzer Prize-winning 1990 book, "The Ants" (Belknap Press), that on the order of 10 quadrillion ants live on the planet at any given moment. That's about 1.4 million ants per human, based on a world population of 7.3 billion people.

4. On every continent . . . but just barely. Although insects can be found by the buckets just about anywhere on Earth, there's one continent where they barely have a foothold: Antarctica. In fact, only one true species of insect, a wingless midge called *Belgica antarctica*, calls the southernmost continent home, according to the Laboratory for Ecophysical Cryobiology at Miami University (Ohio). The tiny fly is only 0.08 to 0.23 inches (0.2 to 0.58 centimeters) long, but it's still the Antarctic's largest terrestrial animal. Amongst this insect's many ingenious adaptations to Antarctic harshness, *B. antarctica* can withstand the freezing of its bodily fluids and sports a rich, purple-black complexion to soak up as much visible sunlight as it can for warmth.

5. Landlubbers. Seeing as you still can't escape insects even in Antarctica, there is one place where you can go to be virtually free of the six-legged creatures. That place is the 70 percent of the Earth's surface covered by the ocean. Why have insects failed to set up shop in the biggest biosphere on the planet? No one really knows why, but suggested explanations are that the oceans lack the plants for food and sheltering habitat that are found on land. Another possible explanation is that a cousin of insects, the crustaceans, have largely made the ocean their home, potentially muscling out their jointed-leg competitors.

6. Breathing through their sides. Insects do not breathe through their mouths. They inhale oxygen and exhale carbon dioxide via holes called spiracles in their exoskeletons. These holes typically line insects' thoraxes and abdomens. Also bizarre: Insect respiratory systems are not patched into the animals' circulatory systems, as they are in humans, where the lungs exchange gases with the bloodstream. Instead, insects have a cardiovascular-like network of tubes, called a tracheal system, which delivers oxygen and ferries away carbon dioxide from each cell in the animals' bodies.

7. Blood bath. Speaking of circulatory systems, insects' are way different from humans'. Rather than closed vessels such as arteries and veins shuttling blood around, insects have an open circulatory system, in which their blood, called "hemolymph," bathes the organs. The insect "heart" is a segmented and chambered vessel running along the animal's back. This vessel contracts to send hemolymph forward toward the head; from there, it sloshes around back into the rest of the body. Hemolympyh is typically clear but can be greenish or yellowish, as anyone knows who has seen certain bugs splatter on their windshield or underfoot.

8. Ancient critters. The oldest insect fossil — a set of jaws, actually — goes back 400 million years, suggesting insects were among the first animals to transition from sea to land. Insects, in other words, were around a good 170 million years before dinosaurs came onto the scene.

9. That's a big bug. The largest insect ever known to have terrorized the skies is *Meganeuropsis*, or the griffinfly, which was an ancient dragonfly with a wingspan of up to 2.5 feet (0.8 meters). These ancient dragonflies preyed on other insects and small amphibianlike creatures during their reign from about 290 million to 250 million years ago.

10. Monsters and motes. The heftiest insect found today is New Zealand's giant weta, a cricketlike beast that can weigh more than a pound. The longest insect, meanwhile, is Chan's megastick, native to the island of Borneo and stretching over 22 inches (66 cm). The smallest insect, you ask? The evocatively named fairyflies from Costa Rica. In one of these wasp species, *Dicopomorpha echmepterygis*, the male is a mere 0.005472 inches (0.014 cm) long.

11. I see you . . . and you, and you, and you, and you! A prominent feature on insects is the compound eye, consisting of many individual visual units called ommatidia. A popular misconception (promulgated tongue-in-cheek in this section title) is that each unit acts as its own eye, each perceiving a total field of view. But in fact ommatidia act more like pixels, building up into a mosaic of imagery. The dragonfly is widely considered to have the most impressively ommatidia-studded compound eyes, with about 30,000 units per half-spheroid eye, according to researchers reporting in a 2012 issue of the online journal PLOS ONE. These ommatidia permit a nearly 360-degree field of view, handy for snatching flying insect prey out of the sky.

12. Bonus eyes. In addition to the two large compound eyes on either side of their heads, a number of insects have so-called simple eyes, or ocelli, in between, smack dab on their "foreheads." Many flying insects' ocelli form a triangle, with two aligned ocelli above a centralized third, looking more like an occult symbol than an independent visual system. The question of the ocelli's function long stymied researchers. Recent studies have reported, however, that the ocelli, at least in dragonflies, seem specialized for detecting light, particularly when distinguishing the horizon, according to scientists writing in a 2007 issue of the journal Vision Research. As such, dragonflies can quickly differentiate up from down, as it were, and keep their bearings during acrobatic flight maneuvers, a feat of attitude-sensing that could work nicely for both piloted and unpiloted aircraft.

13. Fast fly-er. Zoom! Jerry Butler, now an emeritus professor of entomology at the University of Florida, once shot a pellet out of an air rifle to see if a male horsefly of the species *Hybomitra hinei wrighti* could catch it. The guy-fly did, suggesting it must have flown at about 90 mph (145 km/h), the record for insects, as reported by Discover Magazine.

14. Methuselah insects. Most insects live for only a few days or weeks as reproducing adults, having spent much longer periods as larvae and pupae, the first two stages of the three-part insect life cycle. There are exceptions, however. Amongst the Hymenoptera order (ants, bees and wasps), the egg-laying queens of colonies can live for decades. In the case of the red

harvester ant, *Pogonomyrmex barbatus*, queens can live perhaps as long as 30 years, according to research published in 2013 in the Journal of Animal Ecology. Taking the top prize are termite queens, which may reign for a half century, according to the USDA.

15. Running out of baby names. Talk about creating a dynasty. Termite queens can produce 6,000 to 7,000 eggs in a single day. An entomologist once recorded a queen of the termite species *Macrotermes hellicosus*, found in Africa and Southeast Asia, cranking out an egg at a rate of one every 2 seconds, which would add up to 43,000 a day, assuming she never took a break, according to the USDA.

16. Mad ups. The records for standing vertical jump for a human are in the 46-inch (117 cm) range, from NFL and NBA players (though there are claims of 64 inches for an amateur athlete, Kevin Bania). Either way, a human cannot jump higher than his or her own height. An insect called a meadow froghopper, species name *Philaenus spumarius*, on the other hand, can jump more than 100 times its height, up to about 28 inches — the insect world record, a scientist reported in 2003 in the journal Nature.

17. Strong as a . . . dung beetle? Scientists reported in 2010 (in the Proceedings of the Royal Society B) that the strongest insect on the planet is *Onthophagus taurus*, known variously as a horned dung beetle, bull-headed dung beetle and taurus scarab. The powerhouse beetle can pull 1,141 times its own body weight.

Admittedly, humans can pull an amazing amount as well. Kevin Fast, a Canadian pastor, holds the Guinness World Record for the heaviest aircraft pulled by a man, a CC-177 Globemaster III that tips the scales at 416,299 lbs. (188,830 kilograms). Fast dragged the behemoth 28 feet (9 m). Assuming he weighs 300 lbs. (136 kg), that's 1,388 times his body weight. Sorry, dung beetle!

18. Insectual healing. Suffice to say, the vagaries of insect sex would take up a whole article unto itself, but here's one fact to walk away with: To prevent competitors from also inseminating female mates, some male insects stay latched to the female for days on end. The male Indian stick insect, *Necroscia sparaxes*, has the record in the scientific literature at 79 days. Admittedly, it's not all sexy-time: Scientists studying a comparatively short mating session of five-and-half-days in different stick insect species found genital contact occurring for only 40 percent of the hookup. Otherwise, a "male clasping organ," specifically a modified set of back legs, kept the female from straying.

19. Can you hear me now? Insects have ears all over the place, yet rarely on their actual heads. Lacewings in the order Neuroptera have ears at the base of their wings. Crickets, including katydids, have thin sound-sensitive membranes on their legs. Grasshoppers' ears appear on their abdomens. The ears of tachinids, a parasitic type of fly, peek out from their necks. Some hawkmoths, meanwhile, apparently can detect ultrasonic vibrations with their mouthparts, all the better for avoiding bats, which use sound to locate prey at night. (To create their own ultrasonic bursts, to drive away bats, hawkmoths rub their genitals together.)

20. All bugs are insects, but not all insects are bugs. Not every insect is a bug. Strictly speaking, "bugs" are an order of insects called Hemiptera. These "true bugs," as entomologists also call them, are distinguished for having hypodermic-needle-like mouthparts. These beaks are perfect for piercing into tissue to slurp up fluids, whether from other insects, plants or — in the case of appropriately named bedbugs — blood from sleeping humans.