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STORM WORLD

HURRICANES, POLITICS, AND THE BATTLE OVER GLOBAL WARMING

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Longtime hurricane specialist Hugh Willoughby has described the Emanuel and Webster studies as precipitating a "paradigm shift"—albeit possibly a false one—within the world of hurricane research. This now ubiquitous and over-applied phrase, which traces back to the theoretical physicist turned historian of science Thomas Kuhn's famous 1962 book *The Structure of Scientific Revolutions,* once had a very specific meaning. According to Kuhn, most of the time researchers in various fields go about conducting "normal science." They study a generally agreed-upon set of questions within an agreed-upon intellectual or methodological framework built upon past achievements. Normal science is predicated, wrote Kuhn, "on the assumption that the scientific community knows what the world is like." So the researchers engaged in normal science go about filling in details, solving puzzles, confirming their theories. They're working within an accepted paradigm.

Sometimes, though, scientific revolutions occur. Kuhn's examples include the Copernican, Newtonian, and Einsteinian ones. In scientific revolutions, an existing paradigm proves unable to account for the anomalies that scientists begin to detect. Eventually, as anomalies accumulate, some scientists start forging a new paradigm. The transition between paradigms is never easy or smooth, however, because other scientists cling to the old paradigm more tightly. In science, wrote Kuhn, "novelty emerges only with difficulty, manifested by resistance, against a background provided by expectation." In fact, in Kuhn's account the resistance to new theories—what some scientists might call institutionalized skepticism—could be said to have a healthy and productive role to play. "By ensuring that the paradigm

will not be too easily surrendered," wrote Kuhn, "resistance guarantees that scientists will not be lightly distracted and that the anomalies that lead to paradigm change will penetrate existing knowledge to the core."

In hurricane science, one paradigm has been built upon the work of Gray and the storm-flying researchers who preceded him. Some of its governing assumptions include empiricism and a practical, life-saving orientation. Hurricanes, in this worldview, are to be studied so as to better understand their formation, structure, and the seasonal variation in their strength and numbers—all of which should, in turn, help save lives and manage risk through the steady improvement of forecasting abilities (whether of storm tracks, intensities, or seasonal frequencies). But the "Gray paradigm" does not include the assumption of systematic changes in hurricanes over time as a result of human-caused climate change. Neither, for that matter, does it pay much attention to the possibility of a dynamic interactive relationship between hurricanes and the large-scale climate system.

In 2005, however, a different set of scientists—Emanuel, Webster and his colleagues—identified what they viewed as dramatic anomalies. And so began the intellectual realignment that defines the early stages of a possible paradigm shift or scientific revolution. To hear Webster's coauthor Judith Curry describe their work is to see this perfectly. "If left to their own devices, the card-carrying tropical cyclone people never would have done the Webster et al. study," Curry commented in an early 2006 interview. "They never would have done it. They knew the answer. There is no change. I didn't realize they hadn't done the work, but they knew the answer. We didn't know the answer so we did the work."

They did the work, and then, as Kuhn would have predicted, resistance set in—a necessary application of professional scrutiny that helps prevent false paradigm shifts from taking hold. There's just one problem: Necessary as it is, resistance isn't always friendly. As Kuhn put it: "Because it demands large-scale paradigm destruction and major shifts in the problems and techniques of normal science, the emergence of new theories is generally preceded by a period of pronounced

professional insecurity." In the case of the hurricane–climate debate, that took the form of attacks on motives and credentials, sometimes very nasty ones.

From today's perspective, however, there's a notable absence in Kuhn's account of scientific revolutions—one of which Kuhn himself seemed well aware. A predominantly historical treatment written well before the evolution of the twenty-four-hour news cycle or the blog-driven chatterological media, Kuhn's study understandably does not explore what happens when possible scientific revolutions get covered live in play-by-play format. Neither does it outline how their dynamics might parallel partisan political commitments during a time of national crisis—so that "resistance," in Kuhn's terminology, takes place on the floor of the U.S. Senate.

Bill Gray quickly fired out detailed rebuttals to the papers by Emanuel and the Webster team. "I just can't have people using data incorrectly," he explained, "particularly if they don't have the experience with it."

Dismissing Emanuel's study, Gray called it "not valid" and "not realistic." He took particular aim at Emanuel's use of data from the Northwest Pacific "over a 3–5 decade period of changing maximum wind measurement techniques." By cubing wind-speed measurements that were of "questionable accuracy," Gray wrote, Emanuel's procedure "greatly exaggerates" any preexisting measurement errors. Gray went on to detail how inconsistent the various methods for determining typhoon intensity—ranging from airborne guesstimates to satellite-based techniques—had been during past decades.

As for the Webster study, Gray once again targeted the data, not only for the Northwest Pacific this time but for every basin but the Atlantic (where he agreed storms had grown more intense but attributed the finding to the Atlantic Multidecadal Oscillation). Here, Gray related his 1978 experience of visiting global tropical cyclone forecasting centers, and remarked that particularly for the North Indian basin and basins in the Southern Hemisphere, "satellite tools and forecaster training" had been inadequate for the task of distinguishing accurately

between different storm intensities. Gray even argued that for the period from 1975 through 1989, forecasters in these regions could not always tell Category 4 and 5 storms from far weaker Category 1 and 2 hurricanes.

Gray also got invited to broadcast his skepticism before Congress. Just days after Rita's landfall, on September 28, he appeared before the Environment and Public Works committee, then chaired by James Inhofe, an Oklahoma Republican who has suggested that the whole climate fuss might be a "hoax." Inhofe continually professes his regard for "sound science," however, and the hearing itself would investigate the "Role of Science in Environmental Policymaking." The headlining witness that day was Gray's hero Michael Crichton, whose novel *State of Fear* involves eco-terrorists conspiring to bring about phony natural disasters and thereby (falsely) convince the world that global warming is underway.

At six foot five and six foot nine respectively, Gray and Crichton towered over the other witnesses, even as they all sat together behind a polished table. Inhofe opened by announcing his delight at having the novelist and film and television producer on hand: "I think I've read most of his books. In fact, I've read them all." "While *State of Fear* is a novel, it is fiction, the footnotes are incontrovertibly scientific," Inhofe added. The Democrats and environmental supporters who followed with their opening statements weren't impressed. Independent James Jeffords of Vermont, the ranking minority member of the committee, demanded to know why, in the face of the disasters that had just befallen the Gulf Coast, Inhofe had called a hearing "that features a fiction writer as a key witness." "It's a work of fiction even if it has footnotes, Mr. Chairman," added Senator Hillary Clinton.

Crichton drew most of the ire from the assembled Democrats, and yet in his presentation he merely read a staid statement criticizing the lack of "independent verification" of many results in climate science (including those of climate models) while never taking on the theory of human-induced global warming directly. By contrast, Gray's testimony was improvised, boomingly loud, confrontational, and oc-

casionally profane. He shouted "damn" and "damn it"; like Henry Piddington, he spoke in language any sailor could understand. He seemed staggeringly out of place in the somber and ornate Senate Dirksen Building hearing room.

Gray began by observing that he'd been "simmering for twenty years" over hyped-up subjects like nuclear winter and global warming. He'd been a lifelong Democrat "until Al Gore ran for president," he explained. Then he outlined his expertise: "I come at this from having spent fifty-two years of my life working very hard down in the trenches, looking at data, working. I've been around the world. I've done forecasting. I've done all these things. And I am appalled at what has come forth." Yet even as Gray denounced expert assessment bodies like the Intergovernmental Panel on Climate Change—"These people that sit on these boards don't know much about how the atmosphere ocean ticks"—he also cracked up the room:

> Just because two curves go up—because we've seen some modest warming in the globe the last three decades and the human-induced greenhouse gases have gone up—does not mean these are necessarily related, that one causes the other. There's a very nice curve I could show that if you look at sunspots and the number of Republicans in the Senate, they go up on about a 10- or 12-year cycle.

From here the testimony only grew more theatrical. A few minutes into his presentation, Gray suddenly sprang up from the witness table and tripped over a microphone cord as he darted across the room to his posterboard and slide presentation. Unselfconscious as ever, he didn't miss a beat. His voice growing louder and louder, Gray launched into his routine about the complexity of the earth-atmosphere system and the shortcomings of modelers who don't issue yearly climate forecasts because "they know they have no damn skill at it." "Should we believe them fifty, a hundred years down the line when they can't forecast six months or a year in the future?" asked Gray. "It's ridiculous," he said, plopping back into his seat but never ceasing to talk for a moment. Before long Gray had likened global warming to the eugenics

movement, an inflammatory analogy that he might have picked up, among other places, from Crichton's novel.

Senator Barbara Boxer, a liberal Democrat from California who would later take over the committee chairmanship after the Democrats regained control of Congress in 2006, did not seem amused. She cross-examined Gray about whether his articles on global warming—not his distinguished hurricane work—had gone through the normal scientific process and been published in peer-reviewed journals. Not seeming to get a straight answer, Boxer pressed further: "Would you not agree, Dr. Gray, that there [are] some very talented people who believe that global warming is a phenomenon, it is occurring?"

"I would agree to that," Gray replied, "and the trouble with that is they don't know how the atmosphere ticks. They're modelers. They're people that make assumptions that are not valid, and they believe them."

"Your attitude is not really very humble," Boxer soon replied. Before long she asked Gray's opinion of NASA's famed climatologist James Hansen.

"I don't know what he knows about the atmosphere," Gray said. "He's not trained as a meteorologist." By the end of the interrogation, Gray was still struggling to keep talking as Boxer cut him off. The transcript speaks for itself:

> BOXER: You just brush away everybody who doesn't agree with you, which I think going in isn't a very scientific thing to do, to prejudge…
> GRAY: There's a lot of us out there that don't agree with…
> BOXER: Dr. Gray, I understand. I understand. But I'm just trying to say something in a friendly way to you. It doesn't help your case to demonize everyone who doesn't agree with you because you wind up [without] very much credibility.
> GRAY: No, it's not everyone doesn't agree with me.
> BOXER: I would like to ask Dr. Crichton a question.
> GRAY: I represent a lot of meteorologists who think very much like I do.
> BOXER: Dr. Gray, my time is running out.

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The 2005 Atlantic hurricane season wasn't about to slow down for the month of October. There were many more records to be shattered. The question was, did each represent a Kuhnian anomaly, or could it be integrated into the existing paradigm?

In mid-month came Hurricane Vince, which originated as a storm with a mix of tropical and extra-tropical attributes but took on clearer tropical features as it moved northeast across the Atlantic. Vince lasted just three days as an official tropical cyclone, and only briefly developed into a weak hurricane northwest of the Madeira Islands. However, this location meant it had achieved hurricane status farther eastward than any other known Atlantic storm. Even though Vince quickly weakened, it held together long enough to come ashore near Huelva, Spain, as a tropical depression, thereby becoming the first recorded tropical cyclone to strike the Iberian peninsula. Vince had weakened so much by then that it didn't cause any real damage, but it did dump significant precipitation. In his final report on the storm, one wag at the National Hurricane Center couldn't resist having a little fun with this. "The rain in Spain was mainly less than 2 inches, although 3.30 inches fell in the plain at Cordoba," wrote forecaster James Franklin.

What Franklin didn't say was that Vince, like all the other seemingly unprecedented storms of 2004 and 2005, posed an unanswered question: Were so many records toppling all at once simply because technology now allowed for better observations of hurricanes? Or might there be some other reason—perhaps a changing climate?

At the very least, the clustering of new records seemed suggestive. If global warming is changing the global distribution or collective characteristics of hurricanes, you would expect to see a slew of storm records broken, just as you would expect to see many temperature records broken. None of these records in and of itself could be *blamed* on global warming, but each would have been made more likely to occur because of it. "In the context of a warming planet," observes Judith Curry, "you see a lot of year-to-year variability, but you'll probably see progressively more records being broken"—specifically, she expects, records for hurricane intensity, season length, and the regional

distribution of storms. And those were precisely the kinds of records set in the Atlantic in 2005.

If Vince was an oddity, Hurricane Wilma, the next record-breaking storm, wasn't the kind of meteorological event that one jokes about. Few were invoking the Flintstones when Wilma, having formed to the east-southeast of Grand Cayman and meandered weakly through the Caribbean for several days, suddenly put on an extraordinary burst of intensification from late on October 18 through early the next day. In only twenty-four hours, Wilma strengthened from a tropical storm with maximum winds close to 70 miles per hour to a Category 5 storm with winds upwards of 170 miles per hour, deepening even more quickly than Rita had a month earlier. This behavior blew out intensity forecasts from the National Hurricane Center, although the experts there knew something dramatic was about to happen. "WILMA HAS DEVELOPED THE DREADED PINHOLE EYE," wrote Jack Beven at 11:00 P.M. on the night of October 18, before the explosion had nearly run its course.

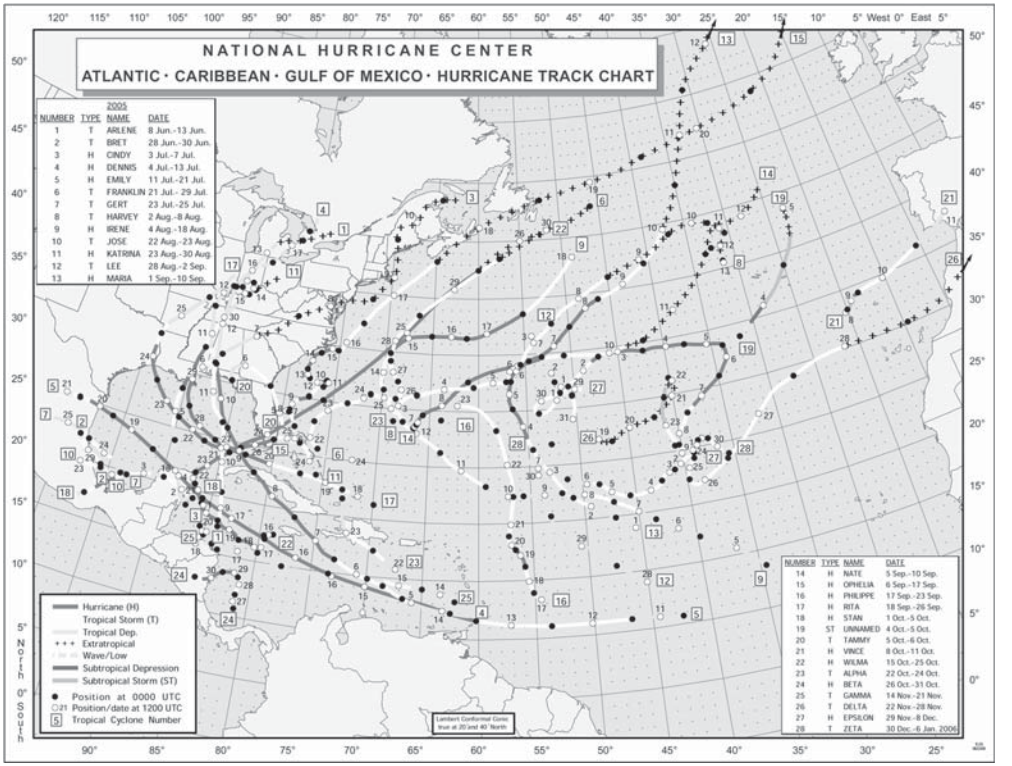
By the next morning, a U.S. Air Force reconnaissance flight that managed to find and penetrate that tiny eye—little more than two miles in diameter at one point, the "smallest eye known" to staff at the National Hurricane Center—had recorded central pressure measurements of 881 and 884 millibars, both unprecedented for the Atlantic basin. The first measurement came from the on-flight meteorologist's extrapolation, the second from a dropsonde released into the tight vortex from the plane. (Later the corrected estimate was given as 882 millibars, or 26.05 inches, although the real value may have been lower.) "THIS IS PROBABLY THE LOWEST MINIMUM PRESSURE EVER OBSERVED IN THE ATLANTIC BASIN AND IS FOLLOWED BY THE 888 MB MINIMUM PRESSURE ASSOCIATED WITH HURRICANE GILBERT IN 1988," wrote forecaster Lixion Avila, the first Miami specialist to comment on the stunning new observations. Avila proceeded to add that "WILMA IS NEAR ITS MAXIMUM POTENTIAL INTENSITY AND FURTHER STRENGTHENING IS NOT ANTICIPATED"—this at a time when maximum sustained winds were estimated at just over 170 miles per hour.

But in fact, the National Hurricane Center's postseason report on Wilma bumped the storm's sustained winds on October 19 up to about 185 miles per hour. It also noted that intensity forecasts during the hurricane's entire lifetime had a persistent low bias, and added that Wilma's pressure drop, 97 millibars in only twenty-four hours, obliterated the previous Atlantic record of 72 millibars in twenty-four hours set by Gilbert. "Wilma's deepening rate over the northwestern Caribbean Sea…was incredible," the report noted. It went without saying that Wilma had been the strongest October Atlantic storm, easily besting Mitch.

As for the destruction: Wilma directly struck the island of Cozumel as a strong Category 4 hurricane and then slowly crossed the northeastern Yucatán peninsula, where the storm expended much of its strength upon the landscape. Then it turned sharply northeast across the Gulf, regained strength in the face of vertical wind shear, and shook southern Florida as a midrange Category 3 storm. Tearing rapidly across the state, Wilma most strongly affected the highly populous Dade, Broward, and Palm Beach counties and caused the largest power outage in Florida history.

In September of 2006, the National Hurricane Center revised Wilma's U.S. damage estimate upward to $20.6 billion, a stunning total that made it the third most destructive storm on record after Katrina and Andrew, and more costly than any of the 2004 storms. To explain this surprisingly large figure, we must look to Wilma's particular path across Florida, as well as its large size. Wilma "had this enormous eye and eye wall that covered the entire southern third of the peninsula," observes National Hurricane Center forecaster Richard Pasch, whose own roof was torn off by the storm.

Although Wilma didn't cause nearly as much death and destruction as Katrina, it was certainly the year's most disturbing hurricane in a purely meteorological sense. The records that it broke—minimum sea level pressure, rate of intensification—were the ones that truly mattered, for they captured the storm's ability to dissipate power and to potentially cause catastrophic damage. If the future would feature storms like Wilma more frequently, then that future sounded like a terrifying place.



Tracks of hurricanes during the 2005 Atlantic season, showing few large stretches of water that did *not* see a storm.
Image credit: National Hurricane Center.

Furthermore, according to the research of Webster, Curry, and colleagues, global warming also appeared to be lengthening the average tropical cyclone season. This made a kind of intuitive sense, as in a warmer world, the tropical oceans would be warmer both earlier and later in the year. For an analysis of season length, the record-breaking 2005 Atlantic hurricane year provided only one data point and could not in itself justify broader conclusions. Still, the fact that the season ran on for more than an extra month, to the very end of the calendar year and even a bit beyond it, is consistent with their argument.

Even before Wilma—which bore the last storm name available—had fully dissipated, the National Hurricane Center turned for the first time to naming storms "after fraternities," as Max Mayfield would later joke. And so came Tropical Storm Alpha (which killed twenty-six people in Haiti and the Dominican Republic), Hurricane Beta (which briefly reached major hurricane strength), Tropical Storm Gamma (which killed thirty-seven in Honduras and Belize), Tropical Storm Delta (whose remnants affected the Canary Islands), and finally Hurricane Epsilon and Tropical Storm Zeta, which stretched into January. All in all, the year featured a total of twenty-eight hurricanes or tropical storms—so many that it almost seemed reasonable to mistake the Atlantic for the Northwest Pacific. In fact, the Atlantic had spawned more total storms than that most active of basins for this particular year.

The previous Atlantic record for storm numbers, set in 1933 before the satellite and storm-flying era, had been twenty-one. Maybe, as Landsea and Gray like to argue, we failed to observe a lot of storms that remained out at sea that year. Or maybe the number of storms and general behavior of the Atlantic in 2005 hinted at the onset of a new climate regime. If true, such a result would not merely have upended an existing paradigm in the world of hurricane science. Within the Bush administration—which had already fumbled in response to Katrina while the entire nation watched, and which wanted nothing less than to see global warming written into that already damaging narrative—the conclusion was so politically explosive that its mere discussion had to be carefully controlled and, in some cases, suppressed outright.